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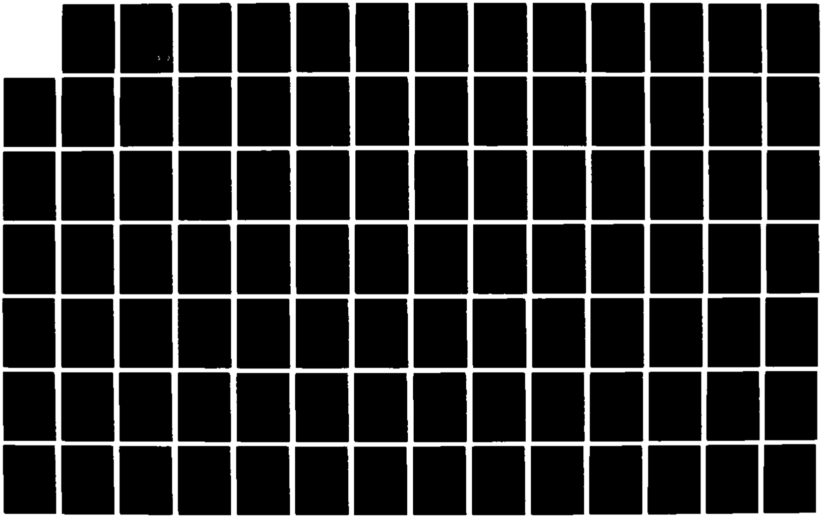

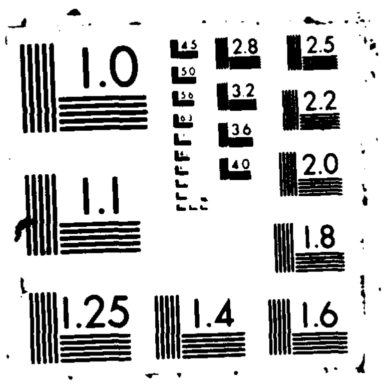
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COMPETITION ANALYSIS MODEL

******CAM******

Analysis Guide
Volume I

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United States Air Force
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COMPETITION ANALYSIS MODEL
Analysis Guide
Volume I

Table of Contents

CHAPTER I

INTRODUCTION

CAM, the Competition Analysis Model, provides the Program Manager with a logical and systematic framework for making informed and sensible decisions about using competition for his project, either at the prime system level or for subsystems and components. The approach presented here is an integrated method for evaluating the costs and benefits of various competitive strategies throughout the acquisition life cycle.

Because there has been little Air Force experience in maintaining competition throughout the entire acquisition cycle, CAM does not attempt to extrapolate from past Air Force experience to make recommendations. Rather it outlines an approach to structuring competition based upon goals and relevant data from the particular program under review. Moreover, CAM provides an approach which allows the program manager to test if the required savings are at least potentially available in the industry directly germane to his particular project.

There are two parts to CAM. One part is this **Analyst's Guide** which offers a comprehensive approach to evaluating the issues which should be considered in deciding upon competition for any project. These factors include the goals of competition, techniques for creating a second source, competition strategies, and the basic cost benefit calculation which should be made.

The second part of CAM consists of user friendly, well documented software for use on IBM-PCs and compatible machines, which does the actual numerical computations.

The computer software integrates all the relevant quantitative factors into one package. The computer model is designed to be used independently of the text and for that reason there are a variety of help messages. Written guidance to using the computer model is provided in Volume II - **Computer Manual.** Volume II concentrates solely on guidance for running the computer model; Users wishing to understand the logic of the computations should consult Volume I - **Analyst's Guide** - which provides a full discussion of input parameters, the computational procedures and the economic issues underlying them.

CHAPTER II

OVERVIEW OF THE MODEL

CAM is designed to provide computational and analytical support to decisions on competition strategy and to provide this support throughout the life of the project. The model performs analyses not only at a detailed level but also with broad aggregations of information. It is, therefore, useful for decisions both early in the acquisition cycle and as a foundation for later detailed analyses. CAM provides support from a SPO's initial, tentative analyses of competition's viability through a formal analysis, available for review and discussion by higher authority and incorporated into an acquisition strategy.

CAM's approach to doing a cost analysis of competition consists of five basic steps. The model begins with a baseline assessment, proceeds to an initial selection of techniques for creating a second source, walks through the basic cost-benefit analysis for the techniques of choice and concludes with describing a proposed justification of the final decisions.

Step I: Baseline Assessment. To make informed decisions, you must first determine the quantitative and qualitative factors you will need to do a cost-benefit analysis. You need to assess your program in terms of four general goals you wish to achieve via competition. You will also assess the program with regard to the relevant industry or firm, the procurement constraints, and the technology. Depending on where you are in the acquisition cycle, the information you have, especially the quantifiable information (like quantity or unit cost) may not be as accurate as it will later in the program's life.

This does not mean that you cannot use it but it does mean that the estimate will be based on assumptions you will have to document in the cost-benefit analysis and later as your confidence in them improves. Chapter III discusses this baseline assessment.

Step II: Establishing a Second Source. The availability and usefulness of alternative producers must be considered. Although the defense market is highly specialized, a variety of producers already exist for most major items. There are several large firms capable of building airframes and acting as system integrators for fighter aircraft. The major subsystems also have a variety of producers. There are two engine manufacturers in the U.S., five aircraft canopy transparency manufacturers, 6 or 7 manufacturers of ejection seats, and a host of firms capable of building avionics equipment. A variety of techniques exist for establishing and qualifying second sources. These are discussed in Chapter IV. After establishing a second source, a competition strategy must be formulated which describes how the buy is to be distributed. Chapter V discusses award strategies.

Step III: Cost-Benefit Analysis. This module provides detailed guidance on how to perform the cost-benefit computations which must be made. Chapter V of this volume provides this discussion. A cost element structure for non-recurring costs is also included. The written procedures are implemented via PC-based software which is designed to calculate the savings required to recover the investment made in the second source. Detailed operating instructions are provided in a separately bound Volume II, entitled Computer Manual.

Step IV: Feasibility Test. After doing the basic breakeven analysis it is necessary to test the feasibility of the required savings. We describe a calculation to determine whether or not the savings needed can be achieved, given the industry (or firm, if already identified) involved. Based on economic data arranged by industry class, percentages

of direct labor, materials, indirect labor, and overhead for each sales dollar have been identified to determine what amount of a price reduction might be offered by a firm in the industry. Chapter VI presents this discussion.

Step V: Wrap-Up. This last part of the model assists in constructing a justification of your decisions to use a particular competition strategy based on factors that respond to your program's needs and the cost-benefit calculation performed. Chapter VII discusses this module.

CHAPTER III

BASELINE ASSESSMENT

This chapter describes the quantitative and programmatic issues which must be addressed in analyzing the use of competition for your program. Creating a baseline assessment will assist you in understanding how competition fits into your acquisition strategy and in identifying and resolving any issues which may impede the successful implementation of competition. The questions are grouped to provide a logical and systematic method for analyzing the myriad of questions which determine whether competition will be effective for your program. This ordered sequence of questions, called checklists, provides the structure for a competition baseline assessment of your program. Answers to individual groups of questions fit into various sections of the model so that other decisions can be made on the way to a final decision. These checklists have been segmented into three categories:

CHECKLIST I: **Goals of Competition**
- Economic
- Programmatic
- Strategic
- Socio-Economic

CHECKLIST II: **Second Sourcing Techniques**
- Phase of the Cycle
- Goals of Competition
- Lead Times
- Technical Complexity

CHECKLIST III: **Cost-Benefit Analysis**
- Quantity
- Duration
- Price Improvement Curve
- First Unit Price
- Investment Cost

Checklist I: Goals of Competition

What do you hope to extract from competition? Clearly establishing the goals you expect to achieve is the first thing to consider when contemplating competition. There are four general categories of goals (benefits) which are commonly attributed to competition:

1. **Economic:** Aimed at unit price reduction either directly, through the use or threat of competitive bidding, or indirectly, through ascertaining comparative cost information.

2. **Programmatic:** Aimed at securing program specific benefits other than price reduction. These include minimizing technical risk, improving quality, accelerating delivery schedules, etc.

3. **Strategic:** Aimed at fulfilling broader service or DOD objectives such as the development of surge or mobilization base capabilities or furthering the technologies which are applicable to programs other than your own.

4. **Socio-Economic:** Aimed at satisfying various national (not just DOD) socio-economic goals such as small and minority business considerations and providing work to labor-surplus areas.

Of the four categories of benefits described above, you will have the greatest flexibility over the first two (economic and programmatic). In most cases, the second two categories (strategic and socio-economic) are usually driven by political necessities which are largely outside of your control. Ideally, it would be best if you were able to maximize all of the benefits that are attributed to competition. While you

may succeed in optimizing several goals, e.g., achieve a broadening of the industrial base and securing lower prices simultaneously, you must recognize that in many instances the satisfaction of one set of objectives comes at the expense of others. Expanding the industrial base can be an expensive undertaking and is unlikely to be consistent with achieving cost, you might be willing to forego certain cost efficiencies. Similarly, driving costs down might come at the expense of forcing a subcontractor out of the defense business. Again, only you can decide whether that's a trade-off you're willing to risk. In addition, trade-offs may not only have to be made within the goals of competition but with other acquisition initiatives that lie outside of competition. For instance, you must be prepared to reconcile competition with the benefits of multi-year procurement or reconcile getting the lowest possible price against accepting international offset agreements which might be costlier.

Checklist Summary

Is competition desired for economic purposes?
- o Reduce price?
- o Gain knowledge of comparative cost or price?
- o Instill cost/price discipline in marketplace?
- o Minimize cost risk?

Is competition desired for programmatic purposes?
- o Minimize technological risk?
- o Minimize cost risk?
- o Minimize schedule risk?
- o Meet unit production goals?

Is competition desired for strategic reasons?
- o Develop a domestic source?
- o Push technology?
- o Increase the size of defense industrial base?
- o Disperse technology throughout defense industrial base?
- o Develop surge capability?

Is competition desired for socio-economic goals:
- o Small/minority business requirements?
- o Labor surplus areas?

Checklist II: ***Second Sourcing Techniques***

A second category of variables you must address in developing a baseline assessment are those which impact the selecting of a technique for establishing a second source. The technique chosen has an impact on the total cost of qualifying a second source since each technique has a different set of costs associated with it. These variables include:

o **Phase of the Cycle.** Where you are in the acquisition cycle has a major impact on the options at your disposal and the opportunity you have to derive benefits from competition. In the past, a scramble for a second source has been a reactive response to schedule or performance problems. This reactive approach has resulted in SPOs which have painted themselves into a corner where they are at a bargaining and legal disadvantage by not having (1) a readily available second source, or (2) the legal/technical means (data rights) of easily qualifying one. As the program matures, certain options will be unavailable unless you have taken various precautions along the way, such as acquiring an adequate TDP.

o **Goals of Competition.** If your primary goal in establishing a second source is programmatic in nature (e.g., schedule considerations such as obtaining as many units as quickly as possible), you can initiate second sourcing efforts before your original source has moved into full production through such methods as leader/follower or licensing. While this allows you to begin the qualification process while concurrently moving your original developer along the acquisition cycle, it does run the risk of incurring engineering change costs, false starts and additional logistics costs. If, on the other hand, your primary goal is economic, you may want to wait until the design has stabilized and article testing has been completed. That too runs the risk of allowing the developer to solidify its proprietary rights or reducing that portion of the total buy which will be awarded on a competitive basis.

o **Lead Times.** You must establish a firm second source "need date". This will allow you to meet schedule and initial operating milestones while at the same time provide the margin necessary to use competition to extract the benefits you're seeking. How long does establishing a second source take? That depends upon how readily available a second source is. Even if a second source is readily available it still takes time to hold a competition, conduct negotiations and a pre-award survey, make an award and qualify the source's first article. As the item moves further and further from being an off-the-shelf substitute, these administrative lead times lengthen with direct impact on costs. An Aviation Week survey of services Competition Advocate has this to say:

"It can take from 6 to 18 months alone to perform the development/non-recurring engineering effort (NRE) to produce a competitive data and drawings package, advocates note. One official noted that it will then take 3 to 6 months to

validate this package and the competition itself will take 9 to 12 months more, much longer than is needed to negotiate or award a sole-source letter contract."[1]

In addition to administrative lead times, also consider production (materiel) lead times. Any choke points along the line of subcontractors will serve to delay the second sourcing process even further. The longer it takes to establish the ability of a new source to produce an item, the larger lead times will be. Long lead times increase the cost of developing and carrying a second source and delays its intended benefits.

o **Technical Complexity:** Generally speaking, the more technically complex the item is, the more difficult it will be to easily second source the item. For example, simple-to-produce items may require little or no interaction between manufacturers and be susceptible to second sourcing during any point during the acquisition cycle. As item complexity increases, the amount of interaction required increases as well. For highly complex items, the second source might have to be brought through the development process from the earliest stages together with the original source or might have to wait until development and testing have provided a stable design. Leader/follower and licensing arrangements might be the best for complex projects.

Checklist III: Cost-Benefit Analysis

The information gathered with this checklist is directly linked to the mathematical cost-benefit calculations you will conduct using the computer model. The cost of competition is your central concern in considering your competition strategy. There is no substitute for a careful calculation of the costs of competition. As correctly stated elsewhere: "it is not enough simply to have faith that the competitive process will lower prices by some amount. A forecast of that amount is needed in order to judge whether gross savings are likely to be sufficiently greater than the costs of opening additional sources of supply to justify both the costs and the risks (of performance problems and delayed delivery) associated with competitive reprocurement."[2] CAM

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[1] "Competition Advocates Cite Time Constraints", **Aviation Week and Space Technology,** Dec 30, 1985, p.25.

[2] K.A. Archibald, A.J. Harman, M.A. Hesse, J.R. Hiller, and G.K. Smith, **Factors Affecting the Use of Competition in Weapon System Acquisition,** The Rand Corporation, February 1981.

addresses methods to help you determine whether or not competition can help you effect cost reductions needed for your program. If the calculations show a loss due to competition, other goals may be achieved and the loss can be considered the price for achieving those goals.

To use the software you will be required to have estimates for:

- **Quantities** - The number of items in the buy, and quantities for each year (or lot). You will also need estimates for how each lot is split between manufacturers.

- **Duration of Program** - Length of the development and production cycle, beginning at the first expenditure of funds for production.

- **Price Improvement Curve** - Estimated price improvement curve for the sole source. If a complete cost benefit analysis is desired you will want the estimated price improvement curve for each manufacturer.

- **First Unit Price** - Estimated price of the first unit. Later, you will need the estimated first unit price for each manufacturer.

- **Investment Cost** - Total investment costs (i.e., non-recurring costs) to establish a second source beginning with full scale development and including production start-up costs. Investment costs for the first source are included in the sole source estimate.

Checklist Summary

- What quantity per year is being purchased?
- How will the quantity be split?
- Over what period of time will production run?
- What is the slope of the price improvement curve for each source?
- What is the estimated first unit cost of the item for each source?
- What are the investment costs for the second source--by year?

CHAPTER IV

TECHNIQUES FOR CREATING SECOND SOURCES

As currently discussed in the literature, in programs, and in contracting offices, there are six techniques available for creating potential second sources to compete for production with a systems developer:

1) Technical Data Package (TDP)
2) Leader/Follower
3) Contractor Teaming
4) Directed Licensing
5) Form, Fit and Function (F^3)
6) Breakout

The first four techniques require the first source to transfer manufacturing know how to the second source to qualify the recipient as an alternative producer for a given system. Whether the transfer involves "hands-on" teaching or the use of data packages these techniques are aimed at providing a second source with the ability to produce a given item so that competition can occur. The last two techniques do not require such transfer. F^3 would directly establish a new source for the capability, while Breakout would have the Government deal directly with an already existing source. The first two techniques can be introduced both during design and production. The remaining four techniques are best confined to production and reprocurement because they assume a mature design.

Each technique is defined below, along with a discussion of their advantages and disadvantages. The chapter concludes with a summary review of the techniques.

TECHNICAL DATA PACKAGE (TDP)

Definition: This technique calls for the creation of a second source through the use of a stand-alone Technical Data Package (TDP) which is purchased by the Government. A TDP is a comprehensive "blueprint" for the production of an item. Ideally, it includes not only detailed design drawings but all other information/documentation required to build an item including descriptions of unique manufacturing and shop practices. Once acquired by the Government it is then provided to firms, allowing them to take steps to qualify as a second source for a product already being manufactured.

TDPs were often compiled and purchased after the Government determined that it wished to pursue competition. This was accomplished through exercise of a Government rights-to-data clause which was usually inserted into the original development contract. While this remains a viable option, the Government is increasingly purchasing the TDP as a separately-priced line item in a contractors development proposal. This procedure is consistent with institutionalizing the ability to compete during subsequent phases of the acquisition cycle. Though its purchase is wasted if never used, experience has taught acquiring it concurrently with development is superior to delaying production in order to acquire and validate the TDP.

This technique cannot be used effectively unless there is thorough system definition, which is usually after production has begun. Further, because of the complexities involved in validating a TDP and adapting its use to the manufacturing facilities of another firm, the TDP technique has been best applied to systems, components and subsystems where design is stable and technology fairly well understood.

Advantages: If the TDP is accurate and complete, it can be used repeatedly to foster competition. In fact, the TDP may never have to be used at all to be of value. The very possession of a TDP by the Government has proven to be effective in exerting downward price pressure if the producer believes that it may be used to qualify a second source. Further, if the TDP is complete and describes a well understood underlying technology, the developer need not contribute "hands-on" assistance and direct contact between the two contractors is not necessary. In instances where the initial producer would be reluctant to assist a potential competitor, this can be a major advantage.

Another advantage to the use of the TDP technique is that once owned, it can be reviewed and improved. A TDP can be provided to a potential second source or a non-manufacturing design firm for review and suggestions for technical and/or cost-cutting engineering change proposals in the item's design or production methods.

Disadvantages: The major disadvantage of the TDP is that Government assumes responsibility for its accuracy. The difficulty of obtaining an accurate and complete TDP cannot be underestimated. Because it is responsible for the TDP, the SPO may require specialized engineering talent to validate the package, which it may not possess in house. If the TDP alone is insufficient to secure effective transfer of manufacturing technology, the Government, not the system developer, is responsible. Even when the drawings and specifications are complete, "hands-on" assistance may also be required to complete the technology transfer. Finally, manufacturers may have such different facilities that a potential second source may never acquire the capability to produce the item, even if the TDP is accurate.

Discussion: While TDP is attractive because it provides the ability to maintain a competitive environment throughout the life of a program, it must be used with caution. Care must be exercised in its preparation and certification. It is particularly unsuited as a technique for unstable and/or untested designs. Historically, even first-rate TDPs have been unable to convey all the nuances of manufacturing a product. Inadequate TDPs result in delays, the need for direct developer assistance, additional project office effort and the risk of legal liability. One example of the TDP technique is that of the AIM-7F Guidance and Control Unit. In this instance, General Dynamics was brought in as a second source during the development phase when Raytheon (the system developer) ran into a number of design problems. The qualification of General Dynamics as a second source consumed over six years and approximately $70 million. Following qualification, several competitions were held to determine how the total buy was to be divided between the two contractors. While early analyses suggested that competition resulted in a significant reduction in unit cost,[3] a more recent analysis of the same data indicates that the net result was a loss of approximately $165 to $190 million (FY 77).[4]

Best Use: The TDP technique is best suited to (a) low to moderately complex items, (b) systems whose design is mature, (c) situations in which some of the risks associated with TDP can be obviated (e.g., shifting certification responsibility back onto the developer).

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[3] James H. Quinn, "The AIM-7F Corp. Pres. to the DSB," NAVAIRSYSCOM, 8/79.

[4] Dr. Michael Beltramo, "A Case Study of the Sparrow AIM-7F," **Program Manager**, September-October 1985.

Some of the means used to overcome the disadvantages of the TDP techniques include:

1) Liability Reduction: The Government has made great strides in recent years in shifting the responsibility for the adequacy of the TDP back onto the developer and for resolution of manufacturing problems back onto the second source through the use of warranties. The contract can be used as the vehicle to require certification of the package's adequacy.

2) Reverse Engineering: The items can be provided to potential second sources for tear-down in order to make the technology transfer process easier and to identify (early-on) any manufacturing or skill deficiencies that the second sources may have.

3) Functionally Identical Substitution: Slavish insistence that the second source must produce completely identical parts may not be necessary if it can provide functionally identical components. Potential second sources ought to be provided the opportunity to suggest value engineering changes and functional part substitution so long as system performance is not comprised and there are no logistical consequences.

LEADER/FOLLOWER

Definition: Leader/Follower calls for the creation of a prime/subcontractor relationship in which the subcontractor is gradually qualified to become a competitor to the prime during the production phase of the acquisition process. In order to qualify the second source, the prime is normally required to share data and other technical information with the subcontractor from the development phase on. Later, the prime is

required to provide assistance to the subcontractor in (a) the transfer of process manufacturing know-how, (b) the creation of a production facility, and (c) the proper execution of a learning buy. The costs for this entire process are absorbed by the Government, usually on a line-item basis.

It is this degree of liaison that distinguishes this method from the TDP technique. In the latter, the Government typically incurs a one-time cost for the documentation required to build an item. In Leader/Follower you must also provide a contract to the original producer for the time/materials required to train the second source in its production methods. Because of the unusual nature of this liaison between potential competitors the Defense Acquisition Regulations (DAR) has several proscriptions concerning its use.

The DAR restricts Leader/Follower to situations wherein:

- The leader company has the necessary production know-how and is able to furnish required assistance to the follower.

- No other source of supply can meet the Government's requirements without the assistance of a leader company.

- The assistance required of the leader company is limited to that which is essential for the follower company to produce the items.

- When its use is authorized in accordance with agency procedures.

The DAR also stipulates the contractual methods used to implement it. It states that the transfer of technical and manufacturing know-how can be accomplished by awarding a prime contract to a:

- Leader company, obliging it to subcontract a designated portion of the required end items to a specified follower company, as well as assisting in the production of the required end items.
- Leader company, for the required assistance to the follower company, and a prime contract to the follower for production of the items.
- Follower company, obligating it to subcontract with a designated leader for the requisite assistance.

Historically, Leader/Follower has been used more for creating a dual source situation than it has as strictly a cost-cutting competitive tool. That is, it is typically invoked not so much to reduce costs (through a desired result) as it has to meet delivery schedules or to mitigate technical/manufacturing risks.

Advantages: One advantage of the Leader/Follower technique is that the transfer of technology is conducted on a contractor-to-contractor basis, with no Government responsibility for the creation and validation of a Technical Data Package (Leader/Follower shares this advantage with Contractor Teaming and Directed Licensing). The presence of the original developer to demonstrate procedures which are difficult to convey through a TDP alone ought to allow for the smoother transfer of manufacturing know-how from one manufacturer to another. This hands-on availability allows for its adoption for more complex items than the TDP technique. Secondly, (warranties aside) Leader/Follower allows the Government to remove itself as the direct

broker of the technology transfer. Though it must monitor and manage the process it does not have responsibility for securing and validating a TDP. The primary advantage of Leader/Follower is that, if started in the design phase, at the start of production two sources are immediately ready.

Disadvantages: Introducing Leader/Follower at a program's outset requires an investment up front to be made in developing and maintaining two sources. One set of costs involved is the development and subsequent maintenance of two production facilities. A second set of costs is incurred in transferring manufacturing know-how; these costs are normally explicitly stated in a Leader/Follower contract. Because Leader/Follower is used in the development phases of a program, the Government's initial investment costs in the potential second source are made several years before production begins (as much as 5 to 10 years). In order to recoup this investment the opportunity to effect large price reductions must be fairly substantial.

Discussion: Careful calculation of costs is required to reveal the economical costs and benefits of establishing a follower. The Leader/Follower technique was developed to address issues of limited capacity rather than cost reduction and thus its ability to reduce program costs cannot be assumed but must be carefully calculated. With the extended time needed to bring a system through the development phase, the data transfer required, and the organizational difficulties associated with implementing Leader/Follower, an astute cost-benefit calculation must be made to ensure that the potential savings from competition will be substantial enough to offset the up-front investment. If the total quantity to be procured is substantial, recovering the up-front investment is more likely. If smaller programs are considered, the potential for large percentage reductions in price should be favorable.

One example of the Leader/Follower approach is in the Air Force's SINCGARS Program. Though it is still too early for a final verdict, the assumptions made in this program appear to reflect the astute use of Leader/Follower. In this instance, the program has committed a substantial amount of funds to maintaining a follower in the hope of exerting price competition once the decision to move into production is made. Given the fact that total program cost is estimated at approximately $7.0 billion, and the projected buy is quite large, the investment appears to be worthwhile even though production is still 7-10 years away. Provided the program isn't cancelled or drastically cut, the chances of recouping tens of millions of dollars over such a large program appear favorable.

Best Use: Leader/Follower is well suited to transferring technology on complex systems because it allows for "hands-on" assistance to properly instruct a second source.

CONTRACTOR TEAMING

Definition: Contractor Teaming calls for the creation of a teaming arrangement between two or more contractors who work as one unit in the design, development and validation of a product or system. Each team member (each contractor) is required to develop the ability to produce the complete item. The team dissolves at the beginning of production in order to engage in head-to-head competition for subsequent production buys. The team can be established either by Government mandate that the prime contractor award a subcontract to another team member, or by allowing the contractors to form a separate entity by their own volition.

Contractor Teaming and joint ventures are not identical. In a normal joint venture, two firms, usually with complementary capabilities, join together and share resources, risk, and rewards to produce a system. Normally, neither firm can independently produce the item the Government wants to purchase. In Contractor Teaming, the key difference is that at the beginning of production each firm will be able to produce the entire item and compete against each other for shares of the total requirement. In either case, the Government gains the technological and production edge of two firms as well as an economic benefit when the firms split up to compete.

A key difference between Leader/Follower and Contractor Teaming is the explicit investment cost incurred by the Government in qualifying a second source under Leader/Follower. These costs may be minimal to non-existent for the Contractor Teaming technique depending upon the structure adopted by the team and the contractual obligations imposed on the team by the Government.

Advantages: Contractor Teaming should reduce or eliminate the feeling on the part of the contractors involved that trade secrets or proprietary data are being "given away." Their mutual dependency to win the award ought to work to suppress the suspicions that might arise under Leader/Follower. Second, it should reduce the problems in qualifying two contractors (since they were involved in the design and initial production, they can be qualified simultaneously). Third, there are no license or royalty fees to be paid, and if the two firms work well together, the design talent of both can be applied to the problem at hand and thereby reduce risk. Fourth, like Leader/Follower, the "synergy" provided by the two firms collaborating on the same item may lead to a superior design than either one could produce independently.

Disadvantages: Contractor Teaming assumes a cooperative effort that may be difficult to realize if the two firms bring different management styles and skills to the table. Sensitivity towards this issue may be overcome best by having the contractors freely select each other, with the Government's approval of the team embedded in the source selection process. The Government must insure that the winning design team will be able to split up and produce a complete system. If they joined together because neither had the ability to meet the requirement individually, then it is unlikely that the collaboration will result in two separately qualified suppliers. Also, in Contractor Teaming, during design, there may be greater expenses since at least two contractors are involved on every proposal. There may be some duplication of overhead costs involved in maintaining two contractors on the same project, as well as duplicative costs incurred during the production phase if both firms are expected to maintain production lines, or portions of production lines, in direct support of the program. Finally, though antitrust enforcement has been relaxed during recent years, its potential involvement cannot be ignored.

One example of Contractor Teaming is the acquisition of the Airborne Self-Protection Jammer. In this instance, two teams of companion industrial firms competed for the final development and initial production contracts. For production however, the winning team will split and then compete against each other. Cost, performance, and logistics support will decide how the production awards are to be split. Though it is too early to judge the ultimate success of the approach, it demonstrates how well Contractor Teaming can work. When the program's goals were to develop the best technical solution to a given requirement it used the cooperation of teamed firms within a design competition. When the goal shifted to price control (during production) it used head-to-head competition to reduce cost.

Discussion: There is rational for adopting Contractor Teaming over Leader/Follower. Schedule or other considerations are usually of major concern in Leader/Follower, but superior design is usually the reason in Contractor Teaming. Contractor Teaming is specifically designed to exploit the technological skills of two manufacturers, while Leader/Follower assumes one developer passes the technology to another. Contractor Teaming does provide the opportunity to engage in price competition for follow-on production since it stipulates that both team members have the capability to produce the end item. Because the cost of bringing two contractors through design, development and initial production is, as with Leader/Follower, fairly high and incurred early, a careful cost-benefit analysis must be performed.

Best Use: Contractor Teaming is well suited to programs where 1) cost reduction is not necessarily the highest priority or the only reason for introducing competition, and where 2) the system under consideration is relatively complex or is pushing the state-of-the art.

DIRECTED LICENSING

Definition: Directed Licensing involves the inclusion of a clause in the early development contract which allows the Government, at its option, to select a second firm as licensee. In return for royalty or technical assistance fees, the development contractor provides the licensee with the data and assistance necessary for becoming a successful second producer. Licensing arrangements can also be made later in the acquisition cycle. When appropriate, the licensor may choose his licensee, subject to Government approval. Directed Licensing is not normally invoked until after the initial source has begun production, because it usually involves a well-defined system.

Advantages: The primary advantage of Directed Licensing is that it allows for the future potential to compete without committing up-front investments in a second source, as in Leader/Follower. It decreases the project office's direct involvement with the technology transfer process. Unlike the TDP approach, the transfer of manufacturing know-how is directly contractor-to-contractor. The Government remains somewhat removed from the liaison and performs only a monitoring function. Once a licensing provision has been included in the developer's FSD contract, the Government can exercise the option any number of times. Because a royalty payment is involved, the initial producer has a legally enforceable obligation to make certain that the second source is able to correctly produce the product. Directed licensing allows for hands-on assistance by the original developer and works to secure his cooperation by compensating it for the immediate assistance and on a per unit basis as well through the payment of royalties.

Disadvantages: The royalty fee to the licensor (the first source) could be so high that the second source, once it has paid the fee, may never succeed in underbidding the first source. Once the first source discerns this inability to outbid, the Government is once again in a sole source environment. Finally, because the licensor maintains its rights to design, design accountability could become complex. For example, the licensee could win an entire production award, but would be unable to change configuration, if required, since the developer retains rights to the design.

Discussion: Licensing is a well understood legal device not necessarily confined to small systems. Licenses have been granted to companies in Japan for the F-15 and to

various NATO nations for the F-16. In licensing, the need is for the system to be well-defined, regardless of its technological complexity. From a cost-benefit view, the licensing fee is equivalent to the technology transfer costs of the Leader/Follower and the documentation costs of the TDP approach. Experience with these other techniques should provide guidance as to appropriate levels of the licensing fee.

Best Use: Directed Licensing is best suited to programs where a data package is almost, but not quite, enough to achieve the transfer of technology from one contractor to another and where the Government wants minimal involvement in the transfer process. Directed Licensing allows for repeated use of the licensing clause for an unlimited number of subsequent reprocurements. It is attractive when the system developer is concerned about losing its rights to design or its role in the creation of a competitor. It is also attractive when the original manufacturer of a system no longer has an interest in the market, even though there is a continuing military need.

FORM, FIT AND FUNCTION (F^3)

Definition: F^3 calls for the creation of additional sources based on their ability to produce an item which meets the performance and external specification requirements of a procurement without regard to internal design. There is no need for a TDP or for interaction between contractors. The Government provides potential second sources with functional specifications regarding overall system or component performance and the size, weight and external configuration, mounting provisions, and interface requirements. Beyond these requirementss the contractor has complete design freedom since the internal configuration of the product is not specified.

Historically, F^3 has been applied primarily to "black boxes" and usually limited to more common, expendable, non-repairable items where concern about internal configuration is minimal.

Advantages: The primary advantage of F^3 is that the costs associated with technology transfer are not incurred since there is no TDP to acquire or liason between contractors as there is with Leader/Follower or Directed Licensing. Second, design is clearly the contractors' responsibility. If the item fails to meet the specifications, the contractor must modify or redesign the item until it does. All of this is not to say that the Government is removed from the process. There remains an engineering workload on the Government's technical staff to ensure that the specifications accurately portray the desired parameters and to judge the acceptability of the offeror's designs. Still, F^3 does represent a lower profile for the Government than the other techniques described above. Another advantage of F^3 us that it allows firms to work to their own manufacturing and design strengths. Rather than forcing firms to adopt the techniques, skills and manufacturing processes of rival firm, it allows each potential source to find its own way towards a common goal.

Disadvantages: If cost reduction is the primary objective then the key disadvantage of F^3 is that unless the item offered is off-the-shelf, each procurement represents a separate development which consumes both time and money. This can apply as well to any unique tooling and test equipment. Second, while the technique may prove advantageous to AFSC, it can cause headaches for AFLC. The provision of non-identical items can make inventory of repair parts and training of maintenance

personnel extremeey difficult. Third, the "fit" element of F^3 is often hard to actually achieve. True interchangeability of subsystems within a larger system can be difficult to ensure. The more unique an item is, the less likely that another item can match its function.

Criteria must be established during the bidding process to assure that the contractor truly understands the work to be done and has accurately priced the effort. It is not unlikely that the contractor with the most optimism about the design will be the low bidder. Finally, it must be recognized that the selected manufacturer is the sole source of this internally configured item. The cost of repair parts will tend to become excessive when a contractor realizes he is in a sole source position with respect to his equipment, unless the total maintenance for the service life of the equipment is provided for in the procurement contract while competition is being maintained.[5]

Discussion: One recent example of the use of the F^3 technique is the Air Force's procurement of the HAVE QUICK system. HAVE QUICK is a relatively simple system developed to fill an immediate need for anti-jam tactical command and control voice communications. Rather than starting from scratch, contractors were asked to incorporate recent advances in synthesizer and large-scale integration technologies into a unit which could be directly plugged into the same envelope as the existing ARC-164 UHF Radio. To date, more than 8,000 units have been fielded at a cost of $3,500 each.

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[5] Benjamin R. Sellers, "Second Sourcing: A Way to Enhance Production Competition", **Program Manager**, May-June 1983.

Best Use: F^3 is best suited to small items, for example, electronic "black boxes", where performance, size, and interface specifications are expected to remain stable over an extended period of time and which are cheap enough to be discarded upon failure. F^3's limited applicability is primarily due to logistics and maintenance factors which must be carefully considered prior to its use. Because of the smaller investment incurred in the qualification of a second source, it may be possible with F^3 to achieve an economic benefit even when quantities are low.

BREAKOUT

Definition: Breakout is a new name for the familiar procurement technique known as GFE (Government Furnished Equipment). In breakout, the Government deals directly with the manufacturer of items (components) previously purchased through a system integrator or prime contractor. Breakout is a technique fundamentally different from the other techniques mentioned above. It is not competition, nor is it a technique for establishing a second source as are the other methods mentioned above. It is a cost reducing measure--properly implemented. Breakout assumes suppliers already exist and that the prime adds nothing but his profit and G&A costs to the item. The purpose of breakout is, then, to eliminate the perceived useless middleman, the prime, by going directly to the supplier.

There are two types of breakout in current use: component breakout and spare parts breakout. Component breakout is used during the acquisition phase of an item. The Government buys the item in question directly from the supplier and provides it to the prime as Government Furnished Equipment to be installed in the production item. Component breakout traditionally has been called GFE. In the Air Force, the Air Force Logistics Command performs the spare parts breakout function (the implementing

regulation is AFR 57-7). Items for consumption in the field (i.e., replenishment spares) are candidates for spare parts breakout. In component breakout, the items broken out would be the engines, avionics, or landing gear; spare parts breakout would be directed at the subassemblies--blades, vanes, circuit cards, wheels and brakes.

Advantages: The goal of breakout is, to save the added G&A and fee costs by having the Government deal directly with the OEM. Unlike the techniques mentioned above, with breakout there is no need for the Government to pay for a learning buy, tooling, or any other costs that are part of establishing a production capability. There are no non-recurring costs (start-up costs) for using these suppliers because they are already producing the item the Government wishes to buy. The economic benefit generated by breakout is simply the difference between the unit price charged the Government by the prime contractor and the unit price charged the Government by the actual supplier.

Disadvantages: There are real costs associated with breakout competition that are potential offsets to the price reduction that breakout offers. Government costs are higher because the Government must take over contracting responsibilities it would not otherwise have. For example, any contract which results from breakout is in addition to the prime contract. Technical monitoring is increased. Cost and schedule problems are the Government's problem, not the prime's. Further, the Government, in dealing directly with the underlying supplier, may not be as free to deal with suppliers as is the prime, and may not be as effective in getting the best price. Regulations and contracting requirements can slow down the project and thereby increase costs as well as force the Program Office to deal with suppliers who are

qualified according to the criteria but are known to be not very capable. Also, some suppliers will not deal directly with the Government because they do not like dealing with the Government or its associated red tape (paperwork, audits, etc.).

Discussion: With breakout, the basic concern is whether or not breaking the item out will save money. In general, chances for major savings are greater with spare parts breakout than with component breakout. With component breakout the Government assumes the risks of not meeting schedule or technical goals. With spare parts breakout the items procured are generally less complex, and are better defined. This difference means lower risks, lower costs to the Government, and greater net savings.

Component Breakout. A narrowly focused cost comparison on whether to use component breakout would almost always show a savings because the Government out of pocket (marginal) costs from the additional contracting is likely to be small and the savings substantial. The nonmonetary, major cost is that the Government takes over the risk from the prime of obtaining the item of acceptable quality and in a timely manner so that the prime can integrate it into the final product.

Spare Parts Breakout. Once a system is operational, it is at a stage in its life cycle where it is defined well enough that the value added by the prime must be considered and questioned. As long as the prime is not performing additional adjustment, refinement or critical integration with the system, the item is a candidate for purchase directly from the supplier and the cost savings are clear and encouraging.

SUMMARY

Exhibit IV-1 summarizes the discussion in this chapter on the advantages and disadvantages of these techniques.

Exhibit IV-1

Second Sourcing Techniques

Advantages and Disadvantages

Technique	Advantages	Disadvantages
LEADER/ FOLLOWER	o No Government liability for technology transfer o Reduces technical, delivery and other risks	o Higher up-front investment costs o Increased administrative burden o Contractor resistance to sharing knowledge
CONTRACTOR TEAMING	o Mutual cooperation decreases resistance o No transfer costs o Synergism can result in technically superior product	o Difficult to get firms to develop systems in tandem o Concern over proprietary data remains o Requires Government monitoring o Potential anti-trust implications
TDP	o Can be reused o Its existence may be sufficient to motivate incumbent to lower price	o Government liable for its completeness and accuracy o It may be insufficient to transfer "know-how" by itself o Requires specialized in-house engineering staff
DIRECTED LICENSING	o License allows for reuse o Decreased program office involvement with technology transfer process o If acquired early, allows for competition potential without much upfront investment or commitment to invest	o Payment of royalty fees can put second source at a disadvantage at bidding time o System developer retains legal rights to design o Cooperation between licensor and licensee may not be forthcoming
F^3	o Design responsibility is the contractor's o No TDP to create or validate (path of least involvement by Government o Each firm matches product to its own manufacturing strengths	o Each procurement entails separate development o Unique tooling and test equipment o True interchangeability difficult to ensure o Spare parts becomes sole-effort situation
BREAKOUT	o No start-up costs	o Government assumes role as prime contractor (find sources, perform acceptance testing etc.)

CHAPTER V

COMPETITION STRATEGIES

The creation of a second source does not by itself represent competition, nor does it have the economic impact (i.e., lower prices) that the proponents of competition wish to achieve. Once two or more sources exist, the question becomes how to create competition between those sources so that the Government derives the most benefit for the system's cost. In general, the DOD has two types of competitive awards: winner-take-all and split buy. Winner-take-all competitions involve the award of 100% of the total procurement to the lowest bidder among two or more qualified firms. Split buy competitions, on the other hand, involve splitting the total procurement between two bidders so that each receives a share of the buy. In addition to the selection of winner-take-all or split buy, the Program Manager may also need to decide whether to hold a single procurement or hold additional competitions (multiple reprocurements). The addition of this dimension results in the four possible options depicted in the matrix below.

	Single Procurement	**Multiple Reprocurements**
Winner-Take-All	Option A	Option B
Dual Source	Option C	Option D

Each option in this matrix has some inherent advantages and disadvantages based on the assumption that contractors will offer different prices, depending upon which option the Government selects and according to what each contractor guesses its opponent will do (this is called "gaming"). Each option has been criticized for tending to "encourage" the potential for price inflation, buy-ins, poor performance, etc. In a split buy, multiple reprocurement situation, there exist several mathematical models

for determining whether or not competition between two contractors will provide an economic benefit. These models usually assume the contractor is "gaming" when he is determining the price to be charged for a weapon system and that he should be penalized for the excessive costs assumed to result from gaming. These models, aimed at discouraging contractor gaming are themselves susceptible to gaming. Aside from the mathematical models, another approach to determining what the savings will be from competition tends to focus on a select number of industrial factors, (e.g., capacity utilization) as indicators of a firm's behavior in a competitive situation. Whether or not these come into play rests on the type of equipment being procured (system, subsystem, component), the industry in question, and a variety of other factors. Nevertheless, each option, even when depicted in the abstract, provides some valuable insights to many of the potential benefits and drawbacks of each competition strategy.

In order to hold a competition, a Program Manager must answer questions similar similar to: Should a single competition be held in which the lowest bidder receives 100% of the total buy? Then, if the lowest bidder is the incumbent, were the costs expended qualifying the second source worthwhile? Should the buy be split in some way so that each source is guaranteed some portion of it? If so, can a contractor be motivated to keep its price as low as possible when it knows that at the very worst it is guaranteed some minimum amount? If the buy is split to attain highly desirable factors like contractor responsiveness, are potential "economies of scale" lost?

The possible ways to structure competition, the mathematical methods frequently used to determine savings from splitting the buy between two contractors, and the economic methods used to determine savings are discussed below.

Option A: Winner-Take-All/Single Procurement

This method involves a competition at the beginning of the production cycle in which the winner is the least cost bidder who is awarded the entire production quantity. This option can be extremely effective in securing a low initial price since it is an all-or-nothing, bidding auction of the traditional competitive situation. As such, contractors ought to engage in a maximum amount of "pencil sharpening". This method has the disadvantage, particularly for large procurements where production takes place over many years, that the Government has now lost much of its leverage over prices through the granting of a **de facto** monopoly to the winner. Critics have charged that this single source producer has no incentive to achieve the cost economics underlying his bid because there is no threat of additional competition. This method can encourage a buy-in. The government must bear the blunt of any cost, schedule, or thechnical problems except as it is willing to again go through the long process of qualifying a second source.

Option B: Winner-Take-All/Multiple Reprocurements

This method involves a series of winner-take-all competitions held throughout the production cycle. This option can discourage buy-ins since the first winner may never get the opportunity to recoup its low bid during subsequent buys if it allows its prices to increase non-competitively. However, the knowledge that there will be additional reprocurements ought to force the first winner to maintain its competitive edge. This option, however, contains a double-sided pitfall in that (1) the loser may never become a true threat since the competitive differential ought to widen over time as the initial winner becomes a more efficient producer through "learning", or that (2) the initial loser then submits a bid so low as to be unrealistic, creating the buy-in problem alluded to earlier.

Option C: Dual Source/Single Procurement

This method involves a **one-time** competition at the beginning of the production cycle leading to a split-buy between two competitors. Options C and A should result in an initial low price as both firms wrestle to gain the larger share of the total procurement. However, both options C and A are assumed to either (a) be susceptible to buy-ins or (b) a form of collusive behavior in which the two competing firms eventually behave as *duopolists*. *In addition*, by selecting the dual source method, it is suggested in these theories that the Government runs the risk of losing whatever competitive benefits it has gained in "industrial inefficiencies":

Option D: Dual Source/Multiple Reprocurements

This method involves a series of split awards in which the ratio of the split is subject to change. Firms are guaranteed at least some portion of the total buy, but poor performance can work to reduce their shares during subsequent buys.

Nonetheless, the perpetuation of a competitive atmosphere offers no solution to the loss of industrial efficiencies just described. They pertain equally in this option. In addition, both types of dual source awards are stated to be susceptible to what is called "low quantity gaming." If a firm is satisfied with a minority share, it is tempted to inflate its prices dramatically, knowing that it cannot "lose", i.e., that is guaranteed at least some portion of the procurement. In this case, competition is more apparent than real since both firms are acting independently to maximize either their price or their profits, based on the unique needs of each company.

Solution Models

To solve the problems that each of these option entails, the Program Manager can refer to a number of econometric models which are designed to elicit the lowest **combined** cost for a given procurement from both contractors. The problems associated with selecting the optimum split are quite complex (as are the solution models) and address such issues as:

- o How to motivate contractors to reduce costs when both are assured at least some portion of the award.

- o How to avoid creating a situation where the contractors create a duopoly that is no more responsive to competitive pressures than the preexisting monopoly.

- o How to reward both contractors sufficiently to ensure that they remain in contention during subsequent competitions if more than one is to be held.

- o In general, how to prevent contractors from "beating the system" by interjecting extraordinary features into the bid process to keep them from "gaming."

Because the solution models to these problems represent lengthy and often highly mathematical discourses themselves, only the key characteristics of the major

approaches are discussed below. For further information on how they are actually manipulated, the reader is advised to refer to the original source material (as noted).[6]

The Minimum Total Cost Rule: The Minimum Total Cost Rule solicits multiple quotations for various percentages of a total fixed quantity (e.g., 30%, 40%, 50%). The contractors' complementary bids are then summed (e.g., A's 30% bid plus B's 70% bid) and the least cost combination for the entire lot is selected. This method is susceptible to gaming however, in that a contractor who is satisfied with a smaller portion has an incentive to raise its quote on the minority share.[7]

The Solinsky Rule: The Solinsky Rule, like the Minimum Total Cost Rule, also solicits multiple quotations from contractors. However, in this case, the quotes are based on various total quantity ranges as opposed to a portion of a single fixed quantity. (For instance, quotations are solicited for total lots of 100-200, 300-500, 600-800, etc., as opposed to 40% or 50% of a fixed quantity). A number of split possibilities are then generated based on the price differential bid for the midpoint range (in this instance that bid for the 300-500 range). Again, however, the Solinsky Rule is susceptible to gaming in that it motivates firms to inflate prices on the high and low ends of the ranges and minimize then only at the midpoint range. This is because

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[6]Each approach is summarized in Defense Systems Management College's **Establishing Competitive Production Sources: A Handbook for Program Managers**, ANADAC, Inc, August 1984. Each is also reviewed in Dan C. Boger and Shu S. Liao, **An Analysis of Quantity-Split and Nonrecurring Costs under Competitive Procurement Environment (Vol. 1)**, September 1985. Source material is foot-noted separately.

[7]J.A. Muller, "Competitive Missile Procurement," **Army Logistician**, Vol. 4, No. 6, November-December 1972.

the midpoint range is used solely for calculating the differential and is not necessarily the actual quantity to be procured. That figure lies outside of the midpoint range where the contractors have knowingly raised their quotations.[8]

The PRO (Profit Related to Offers) Rule: One of the more innovative approaches was that developed by the Navy's Strategic Systems Project Office. The PRO rule avoids the problem of low quantity bid gaming by always splitting the award on a 50-50 basis. However, downward pressure on price is exerted through the use of 1) fixed-price incentive contracts, 2) the use of competitive price ranges determined by the project office itself prior to the solicitation of bids, and 3) siding profit scales based on the differentials between the high and low bid.[9]

The Pelzer Rule: The Pelzer rule attempts to incorporate quality considerations into the calculation. Without going into the econometric details of the model, the Pelzer rule first establishes a competitor index based solely on price which is derived from quotations on various quantity ranges which are also spread over a three year period. Second, a separate equation is set up which weights various qualitative factors such as poor performance or late delivery as evidenced from the contractor's prior two-year history. The weight each factor receives is variable depending on its

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[8]Kenneth S. Solinsky, "A Procurement Strategy for Achieving Effective Competition While Preserving an Industrial Mobilization Base," U.S. Army Electronics R&D Command, Night Vision and Electro-Optics Laboratory (undated).

[9]Based on materials provided by John Dunagan of SSPO to J.W. Drinnon on 7 July 1983. This material included: K.V. Fleming, "The PRO Concept," February 1980.

importance to the overall factor. The more important it is, the higher is the assigned weighted constant. Finally, the price index and the performance index are combined to give a total index which varies according to different split ratios.[10]

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[10]Jay L. Pelzer, "Proposed Allocation Technique for a Two-Contractor Procurement," Air Force Institute of Technology, May 1979.

CHAPTER VI

COST-BENEFIT ANALYSES

"What will the savings be due to competition?" This question is inevitably asked when a project is considering the use of competition. This chapter discusses the basic cost analyses which must be accomplished in order to evaluate the cost impact of a particular competition strategy. An understanding of these issues is vital to understanding the cost issues involved in introducing competition. The costs of creating a second source (the investment) must be compared to the benefit where the benefit is defined to be a lower price than the sole source price. There are two approaches to estimating the cost impact of competition. One is the savings approach, the other is breakeven analysis. CAM's software allows the user the choice of which to use. This chapter first outlines carefully the savings approach to analyzing the impact of competition. This discussion shows the detailed information which is required to directly estimate savings. Then a detailed discussion of breakeven analysis is presented. This discussion shows that fewer assumptions are required but less insight is gained. Before discussing savings and breakeven analysis, two analytical techniques are discussed which are commonly used in doing cost analyses of competition: price improvement curves and net present value analysis.

Analytical Foundations

Price Improvement Curves. It is impossible to discuss how savings due to competition are analyzed and calculated without first recognizing the existence of price improvement curves (PICs) and their estimated shift and rotation due to competition. Because PICs are a recognized tool of cost analysts, the discussion here assumes the reader understands their underlying theory and computational

procedures. A discussion of PICs and the shift and rotation hypothesis is presented in Appendix A. Competition is asserted to affect PIC's by causing a shift, an immediate price reduction, and rotation, or steeper slope due to efficiency. Shift and rotation are useful analytical concepts to examine the influence of competition. The difficulty lies in estimating the amount of shift and rotation which will result from introducing competition in a particular procurement. Such estimation is acknowledged by experienced analysts to be difficult and based on limited empirical data for weapon systems. It is for that reason that some analysts prefer the breakeven approach to estimating the impact of competition.

Present Value Analysis. In using competition, the Government absorbs a number of upfront costs that it recoups by later paying a lower unit price for the product than it would otherwise have paid the initial, sole source. A rigorous analysis requires the time phased predictions of the projected stream of costs and savings which should be discounted back to the date of the initial investment. This "discounted cash flow analysis" makes comparisons of alternative investments possible and is essential to determine whether there has been a savings or loss, given the timing of the investment and the timing of the savings that it produces. CAM uses this net present value analysis.

The Savings Analysis of Competition

All analyses of the savings from competition must have a base from which to compute the savings. That base is the estimated total cost to the Government if a sole-source procurement were to be utilized. The savings analysis compares that cost to be estimated then estimate the total cost of dual source case which includes, as one major item, the investment costs of creating the second source. Savings are

computed as the difference between the sole source cost and the two source cost. The computation takes the general form:

(1)	Sole Source Recurring Costs for Entire Buy	-	Dual Source Recurring Cost for Entire Buy	+	Additional Non-Recurring Costs	=	Savings Due to Competition

There are, however, several distinct analytical steps which must be taken before this straightforward calculation can be performed.

Sole Source. First, the cost analyst must estimate the total costs that would be incurred if sole source procurements were utilized. For recurring costs, this step requires the first unit cost and learning curve slope for the sole source producer and annual lot quantities. If production contracts have been let then these values are already known; otherwise they must be estimated. (If only the first lot costs are known then the first unit cost can be derived from that data point and the slope of the learning curve.) For projects not in production, one obvious source of data on learning curve slopes are recent procurements on similar equipment procured sole source.

The next step in this approach is to identify costs by year so that the net present value can be calculated. CAM uses the following formula to compute the annual cost:

$$(2)\quad C(N_1,N_0) = A/(B+1) * [N_1^{B+1}-N_0^{B+1}]$$

where,

A is the first unit price

B is the exponent of learning: ln(learning curve slope)/ln(2)

and $C(N_1,N_0)$ = the cost of producing units from N_0 through N_1. The total units produced in a lot = N_1-N_0+1.[11]

Then each annual cost is discounted back to the base year with the standard formula for net present value. CAM asks the cost analyst to supply the discount rate. OMB circular A109 requests that Government analysis use a 10% discount rate.

Non recurring costs for the sole source case should also be estimated. If a production contract has already been let then these costs for the sole source producer are already known; if not they must be estimated. Because of the importance of investment costs, a separate discussion on them is presented below.

Dual Source. The cost analyst must compute next the total costs for the dual source case. Recurring costs for each producer are computed using an assumption about that producer's share of the total buy and an assumption as to his PIC curve after competition. Shift and rotation analyses are required here. The total recurring cost for the dual source case is the sum of the recurring cost for each of the two producers. It is assumed that the Government will use a split buy award strategy where quantity Q for each year in the sole-source case is split between the two

[11]This equation relation between this formula and the unit cost is derived in Appendix A.

manufacturers Q_1 and Q_2. The split is determined as part of the award strategy (see Chapter V) decided upon for this contract. Any split is possible although in most procurements some minimum is required to keep the smaller producer's production line open at an economical level. Standard percentages are 60-40 and 70-30. CAM allows both a percentage split and a quantity to be specified annually. Then CAM uses equation (2) above to compute the annual cost for each producer. These two costs are then summed to get total recurring costs for the dual source case and then the net present value is found.

Obviously some sensitivity analysis can be done here if one explores various assumptions about the impact of competition. CAM has two built in computational aids to sensitivity analyses. One computes what the second source first unit cost would be to breakeven, next, the cost analyst must compute the total costs for the dual source case.

Next, the additional investment required in the second source case must be estimated. These additional costs includes, of course, all the investment costs for the second source. They also include the adjustments to the sole source's nonrecurring costs. Some of these adjustments might be downward. For example, special tooling requirement might be lowered because the first source will not be computing the entire quantity. However, there may be additional costs, such as preparing a TDP, that would not be incurred if there were no second source. The time pattern of incurring these investment costs must be estimated in order to use a net present value calculation. This is important because the time pattern for incurring these costs vary significantly from technique to technique.

The above approach is the basis of computing of savings from competition and shows that estimated savings clearly depend heavily upon assumptions about shift and rotation. Obviously, competition can only create savings if the recurring costs of the dual source case are sufficiently less that the cost of the sole source case, to more than offset not only the additional investment costs but also the higher per unit cost because the buy is being split. For a learning curve of 90%, splitting the buy in half raises the average cost 11.1%. The direct computation of the savings can only be done provided that you estimate what the shift and rotation will be. It is not enough to have an estimate of the expected percentage savings because a given percentage price reduction can be accomplished by an infinite combination of shifts and rotations. The savings analysis requires that the estimated shift and rotation resulting from competition be precisely stated (e.g., that the second source has a 5% shift and a 3% rotation as a result of introducing competition).

Breakeven Analysis

Breakeven analyses is an alternative to the traditional savings approach to estimating the cost impact of competition. Breakeven analysis calculates the percentage reduction in the cumulative average unit cost in the sole source case that must be achieved in order to offset the extra costs of competition. While this percentage value does not by itself indicate whether competition will payoff, it is a number that can be checked for feasibility by a variety of techniques, including the use of easily available economic data incorporated in CAM. (In contrast, there is little publicly available data on observed shift and rotation resulting from competition.)

Breakeven analysis reduces the number, and to some degree the significance of, the assumptions which must be made to analyze the savings from competition. In

particular, breakeven analysis eliminates estimating the shift and rotation of the price improvement curve as a result of competition and does not require that price reductions be identified to either one manufacturer or the other.

Computing the breakeven point proceeds in the following way. Breakeven analysis uses as a baseline the total costs assumed to exist under sole-source conditions. The recurring costs in the sole-source case are estimated as before using equation (2) and production quantities for each year. The net present value of each annual cost is then computed and summed. As before, this sum is the net present value of the recurring costs of the total buy in the sole source case. As before, investment costs for both the sole source and dual source case are estimated and their net present value found. The cost issues involved are the same.

As implemented in CAM, the breakeven calculation can then at this point proceed in two ways. One way requires no additional assumptions and calculates the savings required from the competed quantities to breakeven without specifying any quantity split between the two producers or shift and rotation. In this formulation the net present value of the additional required investment is divided by the the net present value of the total costs in the sole source case to calculate the percentage price reduction which competition must cause to breakeven. Equation (3) describes the general calculation to determine the price reduction needed to recover the investment in competition.

$$\text{(3)} \quad \frac{\text{NPV of Investment}}{\text{NPV of Total Buy}} = \begin{array}{l}\text{Per Unit Price}\\ \text{Reduction Required}\end{array}$$

As originally proposed, the breakeven analysis only considered the savings required by the second source. In this variation, the cost analyst was assumed to know what sole source would do under competition (i.e., what his shift and rotation would be).

CAM allows the analyst to compute this breakeven point in either of the two ways. CAM's software also allows this approach to be used for a program later in its life where some units have been procured sole source and the question to be answered is what the savings have to be to breakeven on the remaining quantity.

Investment Costs

Determining the investment cost of competition is a major part of the required cost-benefit analysis. (These costs are also called nonrecurring costs or start-up costs.) The general failure to properly consider investment costs, when analyzing the effect of competition, has been largely responsible for the lengthy and spirited debate over estimated savings due to competition. Estimating investment costs is a cost analysis exercise which must be accomplished outside of CAM and completed before any computations are performed by CAM. Investment costs should include all the costs required to get a second source into production that would not have been incurred in the absence of competition. While there is no agreed upon set of nonrecurring costs, the following is a good beginning.

System Engineering/Project Management

Tooling and Test Equipment

Test and Evaluation

Data

Technical Data Package

These items are consistent with the data submitted by contractors in DD Form 1921 and should be readily available for similar projects.

The first source costs include those nonrecurring costs which the first source would not have incurred if there had been no second source. An example of these costs might be preparation of the TDP. For projects early in their acquisition cycle, these costs will have to be estimated. Later they will probably appear as separately priced line items in contracts. Second source costs include all nonrecurring costs associated with creating an alternative production source, including the above items as well as a learning buy, licensing fee and other costs.

Several issues are relevant to estimating investment costs. One is that while CAM only uses the total for nonrecurring costs by fiscal year, estimating nonrecurring costs by component is probably the best way to proceed. One reason is that comprehensiveness is more readily assured. Another reason is that the various components vary in their differential impact as between sole source, prime source and second source and as noted below, between techniques for establishing a second source. For example, special tooling and test equipment will probably be related to the quantity to be produced by that bidder. If a 70-30 split is envisioned then each producer must be funded to have a production capacity of 70% or 140% of the production capacity that would be funded in the sole source case. Other non recurring costs probably will not vary much at all with changes in quantity. A third reason is that the time phasing of these various categories of non recurring costs varies depending upon whether leader/follower or teaming, for example, is used. A careful cost analysis requires that these costs be estimated by year.

The investment costs required to create a second source will vary from technique to technique. A brief review of the costs associated with each technique is provided in Table VI-1. Clearly not all techniques for creating a second source would incur all the costs. For example only F^3 would normally incur a second set of R&D costs. The major costs involved with the second sources are those associated with production start-up and test and evaluation. These are costs that would not be incurred in the absence of competition and which represent a cost of using competition. Careful attention must be paid to estimating these costs. Bid and Proposal and Project Management are costs that also need to be considered. Licensing fees must be included if directed licensing is to be used as a second sourcing technique. Data costs for the second source should include those expenses incurred by the second source to take the data package received from the first source and redo it for the peculiarities of their own manufacturing plant and procedures. For example, the second source might have to prepare technical manuals and drawings for use on its own production lines. A comprehensive cost analysis would also include the differential costs of the learning buy for the second source, i.e., the extra costs of producing those units over what the sole source would do.

Government Costs. The Government incurs extra costs when competition is used. Some of the Government's additional investment costs, both in development and in production, are out of pocket costs, such as range charges or the cost of a contracted-out review of a TDP, which are easy to determine because they are already quantified. Some costs are difficult to quantify because their quantification is difficult or impossible. For example, risk to a program because of schedule or technical slippage as a result of competition is a danger not easily quantified. Some

Table VI-1

Second Sourcing Techniques/Cost
Element Matrix

	TDP	L/F	CT	DL	F3	B/O
Production & Technology Transfer - Related						
TDP Preparation	√	√		√		●
TDP Review By a Design Agent	●			●		
Contractor - to Contractor Liaison		√	√	●		
Learning Buys	●	√		●		
Reverse Engineering	●	●		●		●
Capital / Facilities Investment	●	●	●	●		
Special Test Equipment Investment	●	●	●	●	√	●
Cost of Maintaining 2nd Source through FSD			√			
Cost of New (2nd) Development Effort					√	
License Fees / Royalties				√		
Production Rate Inefficiencies	●	●	●	●	●	●
Government & Administrative Related						
TDP Validation	√	√		√		√
Government Inspection / Surveillance	●	●	●	●	●	●
Contract Administration	●	●	●	●	●	√
Product Certification - (Opeval, Techeval)	●	●	●	●	√	√
Configuration Management Responsibilities	●	●	●	●	√	√
Logistics Related						
Duplicative Inventory Costs					√	
Duplicative Training, Documentation					√	
Preservation, Package, Shipping	●	●	●	●	●	●

√ Usually Incurred
● Potentially Incurred

costs difficult to quantify because of conceptual difficulties is the cost to the Government of its personnel for additional program administration responsibilities due to competition. Clearly competition involves more work Government personnel, estimating that cost is difficult at best. Any analysis should note whether or not the cost of Government personnel is included, and if they are, how that cost was determined.

CHAPTER VII

FEASIBILITY TESTS

The end result of the breakeven analysis described in the preceding chapter shows the percentage price reduction needed to make competition pay off--but to finish the cost-benefit analysis you need to determine how likely such a price reduction will be and where it might come from. Determining feasible price reductions have always been difficult. Early efforts to establish feasible price reductions consisted of assertions that competition would reduce program costs by 25%. More recent efforts to establish feasible price reductions come in the form of estimates of shift and rotation of PIC's resulting from competition. Normally one would use historical data to estimate appropriate values for shift and rotation. However the data base available to the cost analyst is relatively limited (as regards large weapon systems) and mixed. Different researchers, examining the same project, have come to significantly different conclusions as to the effect of competition. In some cases, one researcher estimated savings while another researcher concluded that competition had negative savings.[12]

The approach presented here is founded on the use of a data base of currently available economic information which contains average costs for each industry by cost category. This approach uses generally available economic data to determine what fractions of a system's cost are attributed to direct labor and materials, i.e. the direct production line costs of production. The fraction remaining is potentially available, within limits, for price reductions. This percentage can be compared to the

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[12] A good review of published studies is contained in CNA professional paper 442, Berg, R., Dennis, R., and Jondrow, J.; Price Analysis and the Effects of Competition, Center for Naval Analyses, October 1985

percentage price reduction computed by the breakeven analysis and comparison of these two figures will reveal whether you are likely to get the price reduction needed. This data, available annually from the Department of Commerce, is described in detail in Appendix B. Appendix C contains the data base to 1983. The details of this approach are contained below, including an algorithm for calculating the feasibility of price reductions.

While the data to be used is an industry average, its utility should not be underestimated. Early in the acquisition process, when you must develop a competition strategy but when you may have little information about the firms that will be producing a system, an analysis of overall industry trends can provide insight into feasibility of savings. As candidate firms become known, the industry data can be compared with an individual firm's data to see how much they vary. This kind of comparison can work as a test of the reasonableness of a firm's costs and can be teamed with other analyses of firms to establish their viability in the competitive arena. At any point in the acquisition cycle where there is a question about savings from competition, an estimate of the savings to be gained from competition can be compared to the data to see if the projected savings are feasible.

Sources of Price Reductions

Fundamentally, there are only three sources of competitively-driven price reductions.

1) The more efficient use of production line labor

2) a. The more efficient use of materials in the manufacturing process or
   b. a reduction in material costs

3) The tighter control or allocation to cost centers of overhead and indirect labor costs.

To tie these potential reductions into our discussion of shift and rotation of learning curves in Appendix A, a shift could be considered 2.b. and 3, while rotation could be considered 1, 2.a., and 2.b. The relative importance of each of these categories, in terms of their availability for potential price reductions, is discussed here.

Labor Costs. While theoretically both the cost of labor and its efficient use affect the price reductions feasible in the labor cost category, labor rates are as a practical matter beyond the control of individual firms. Reductions in labor wage rates are not going to be a significant source of immediate price reductions although they might be available over the long term.

However, more efficient use of labor is a source of price reductions under control of individual firms. For the defense-related industries we have included, production line labor as a percent of sales varies from a low of 6.4% (SIC 3573, Electronic Computing Equipment) to a high of 31% (SIC 3544, Special Dies, Tools, Jigs, etc.). The range 10.5% to 16% covers most of the SICs listed. Therefore, direct (touch) labor costs are a relatively small proportion of final price, particularly for most of the "hi-tech" industries of interest to the DOD. Because labor costs are a relatively small portion of the total costs, in the normally highly capital intensive industries associated with defense manufacturers, it is possible to achieve only a small reduction in price due to reductions in labor costs.

Material Costs. Material costs in all of the industries included are a relatively substantial proportion of total costs. Material costs as a percent of sales vary from a low of 24% (SIC 3622, Industrial Controls) to a high of 65% (SIC 3313, Electrometallurgical Products). The bulk of these costs represent funds used to purchase materials, components and other supplies. If these are being purchased from a broad range of already competitive suppliers, it is unlikely that a second source competitor can obtain major price reductions for these costs that is not already available to the initial sole source producer.

One possible exception to this conclusion is that of a highly capital intensive firm whose ratio of "make" to "buy" decisions is heavily skewed towards "make", i.e. in-house manufacture, of as many items as possible. Because such a firm would buy substantially more material, it may be able to generate significant cost savings, particularly if materials are not competitively purchased. In this case, potential reductions in material costs could be quite large.

Indirect Labor, Overhead Costs, and Profits. After considering direct labor and materials costs, the costs that remain are indirect labor, other overhead costs, and profits. Substantial cost reductions may be derived from these categories for two reasons. One, overhead costs are not directly related to the output, and changing business conditions can change overhead rates. Two, within limits, allocation of these costs to the final price of a specific product is under the control of senior management. This means that these costs can be allocated, at least in part, to meet the requirements of competitive conditions. For example, recent empirical research has shown that the slope of price

improvement curve can be affected by the choice of depreciation (accelerated vs. straight-line) and inventory valuation methods (LIFO vs. FIFO). These cost categories therefore ought to be the ones most able to be influenced in a competitive situation.

An Algorithm For Calculating A Feasible Price Reduction

Based on the above discussion, a standard formula has been devised for use with the industry data for determining the feasibility of competitively-driven price reductions.

$$P(R) = (OH - ((.4DL + .1MC) + 1.4IL)) + 1.1(DL + MC) \text{ where:}$$

P(R) = Price Reduction (percentage)
OH = Overhead Rate
DL = Direct Labor
MC = Material Costs, and
IL = Indirect Labor

In calculating the potential for price reduction, the values for the variables are derived from an analysis of trends in the economic data. The example section below reveals the derivation of these factors. The coefficients are our recommendations of the adjustments and are based on common business practice. These coefficients can be changed if there is evidence of a need for it. This formula can be applied to all of the industries represented by the data.

Basis for Coefficients

In order to determine the level of price reductions that may be gained, certain adjustments to direct and indirect labor and material costs are required.

1) Based on fringe benefit payment ratios and employment taxes (FICA and FUTA can run as high as 10%), a 40% upward adjustment should normally be made

to the direct labor costs used in the Commerce data.

2) Based on handling and inventory related costs, a 10% upward adjustment should be made to material costs.

3) Indirect labor costs also require an upward adjustment of 40% for the same reasons as the direct labor costs.

These adjustments are what would be considered reasonable and normal. Adjustments for labor costs can be refined through the acquisition process; for example when the manufacturers are known, their loaded labor rates will show the manufacturer-specific upward adjustment for direct and indirect labor. The 10% adjustment in (2) above is actually a lower limit; research suggests that manufacturers are charging "handling" costs as high as 40% with little or no value-added. If higher weights on handling costs appear justified, the coefficient may be changed.

Example

Deriving the variables to be used is a matter of analyzing the trends exhibited by the economic data. Clearly, any trend analysis would be enhanced by an understanding of the underlying forces that shape the trends. In this example we use the aircraft engine and spare parts industry data to derive values for the variables.

Direct Labor: As shown in Exhibit I, direct labor costs in the aircraft engine industry for the five years ended in 1983 moved downward from

approximately 15.7% of sales to 12.8%. These figures are not significantly different than the direct labor ratios experienced in the ten years subsequent to the Vietnam War (1970). Based on this data, an assumption of direct labor costs at 14% of sales (a simple average over the last five years) appears warranted. Therefore, DL = 14.

Material Costs: With the exception of 1981, material costs as a percent of sales for the ten years ending in 1983 ranged between 43% and 47% of sales. Dropping 1981, material costs of 45% of sales is reasonable. Therefore, MC = 45.

Indirect Labor Costs: A similar review of the indirect labor costs for the last five years shows that they varied between 12% and 13% of sales. These figures are constant enough to use an average of them (12.5%) for predictive purposes. Total labor costs as a percent of sales also varied within a very narrow range, i.e., between 25% and 26% of sales suggesting that labor costs as a percent of sales has been very stable. Therefore, IL = 12.5.

Thus, production line costs for manufacturing aircraft engines and parts represent approximately 59% (14% for direct labor plus 45% for material costs) of sales. The remaining 41 cents out of every dollar of sales is accounted for by overhead costs and profits.

Adjustments. The adjustments noted above are then applied. The first two adjustments increase production line costs from an estimated 59% of final price to 69.1% (14x1.4 plus 45x1.1 = 69.1). This adjustment reduces to 30.9% of sales the dollars available for "shaving" a price in order to meet a highly competitive

situation. The third adjustment is to indirect labor, which accounts for 12% to 13% of sales. After the 40% adjustment, these costs account for 16.8% to 18.2% of sales (an average of 17.5%). Given the business realities of the defense industry, it is unlikely that senior management will in the short run reduce these costs in order to be competitive. This then serves to reduce to approximately 13% (30.9-17.5) the potential for competitively-driven price reductions in this industry.

Some further reductions may be obtained. A working hypothesis is that a competitively-driven 10% reduction in the total of all production line costs (direct labor costs + material costs) is possible. For our example, that adjustment would add approximately 5.9% (10% of 59%) to the potential price reduction. The final calculation shows that the maximum feasible price reduction for an average firm in that industry is 19% (13% plus 5.9%).

CHAPTER VIII

WRAP-UP

The last part of the model provides a structure for integrating and summarizing the results of the previous steps into a paper that justifies the competition strategy chosen based upon the cost-benefit analyses performed. Once this paper is complete, any reevaluation of the basic cost-benefit analysis required will become evident. Some reevaluation will take place naturally over the acquisition cycle as better or revised information is available. But more generally, it is now, when all the information, analyses, and computations pertaining to competition are assembled, that the need for further analyses or revised analyses will be obvious.

A review of the information assembled initially will reveal either a favorable or unfavorable imbalance between costs and benefits for a particular competition strategy. Major savings due to a competition strategy may be clearly within grasp, or costs of competition could significantly outweigh the benefits. It is also possible that the effect of a competition strategy could be almost neutral--for example, the costs might be slight and so might the benefits. What is required is a systematic evaluation of all assumptions leading to this conclusion as well as careful consideration of likely changes to these assumptions. The structure presented here allows for changes to earlier assumptions being easily accommodated so that the effects of change can be seen. Also, if there is more detail as the program changes or progresses, the structure described here allows for the analysis to be revised systematically. With each iteration, you return to this part of the model to document, in a logical way, the steps taken, the analyses performed, and the conclusions reached.

Structure of the Cost-Benefit Justification

The recommended structure of the justification follows the steps of the model, except that System Definition and Goals for Competition are additional categories needed for focus. The categories are:

System Definition

Goals for Competition

Second Sourcing Technique

Basic Cost Analysis

Feasibility Analysis

Conclusion

Below we describe the issues that should be considered in each of these categories.

System Definition

Describe the system to be purchased. For a major system (e.g., an air vehicle) also describe the major subsystems. This description may be technical or classified or it may be rather basic. In any case, it should be thorough enough to set the stage for the analysis that follows. The choices made later, including business and quantitative decisions, should be consistent with this discussion. For example, the subsystem discussion should describe existing subcontractors arrangements so that any subsequent discussion of breakout competition is understood.

Goals For Competition

Describe the primary purpose for using competition: also describe secondary purposes for using competition. The goals, primary and secondary, are the measure by which the effectiveness of competition for your particular project can be assessed. The goals for competition should have been identified within Module 1, Baseline

Assessment. The purpose of the discussion here is not to repeat the general statement of what competition can accomplish but to state explicitly which of these goals you have set for your project and why. Whatever goals are stated as having been chosen should be the basis for subsequent analysis. For example, if cost reduction is the primary goal for competition, then the cost-benefit analyses should be primarily highlighted.

Second Sourcing Technique

Describe here the methods that were considered for establishing a second source and the reasons why it is not necessary. If you have developed a new approach to establishing a second source, describe it here. If the method proposed for your project is a combination of existing methods, here you describe them and their use. Of the methods considered, identify those which were selected tentatively for cost-benefit evaluation. The techniques for establishing a second source are described in Chapter 4, Techniques for Establishing Second Sources.

Cost-Benefit Calculation

The analysis and evaluation of all relevant costs is vital to the selection of the appropriate competition strategy. The purpose of the cost-benefit analysis in module III was to explore and quantify the relative advantages of different methods. The need in this justification paper is to describe the inputs you made for each of the techniques examined, including identification of investment costs for each second sourcing technique. Briefly describe here the results of the calculation performed by the software for each of the techniques considered. This description of output could take the shape of a nxm matrix, for example, where n is the number of sole source case situations and m is the number of techniques. A more complex matrix

could include, for example, various quantities of an item so that you could see the effect of quantity changes on price reductions for each technique.

After arranging the data in such a matrix, you should identify technology transfer and sole source case options that are feasible and that will meet the price reduction needed in order of size of price reduction if price reduction is a goal, or in order of least cost (smallest negative price reduction) if other goals are primary. The feasibility test described earlier helps you identify feasible price reductions.

Feasibility Test

Describe here the results of the feasibility calculations. These should include the both the feasibility examinations, which checked for the feasibility of the needed price reductions and the sensitivity tests which considered how the reasonable variations in the values used affected the results.

It is here that the uncertainty surrounding these input variables should be systematically explored. Estimates of future costs are beset by uncertainties from many sources. It is therefore useful to perform sensitivity analyses that show the range of uncertainty and explain the thinking used to establish the bounds of that range. What needs to be established is if any conclusions as to the appropriate course of action are likely to be revised if the upper ranges of some key parameters are used rather than the lower end. The factors that are examined should include these which are likely to change, such as the quantity to be procured.

Describe any other feasibility determinations at this point, for example, reviews of capacity utilization for the industry, or assessments of financial conditions for

individual companies that you believe would be, or would want to be, involved in the competition.

Conclusion

The discussion here is really a summary that concludes the analysis. It provides a clear explanation of why the particular techniques for establishing a second source decided upon for your project based on program and cost considerations.

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APPENDIX A

Learning Curves and Price Improvement Curves

Cost analyses of weapon systems inevitably makes use of learning curves, the mathematical relationship that describes the reduction in unit prices as cumulative production of the item increased. Originally, learning curves were used to describe the reduction in labor hours as quantities of an item increase. When applied to all costs (not just labor hours), learning curves are also called Price Improvement Curves (PICs). Both learning curves and price improvement curves describe a phenomenon that has been observed repeatedly in real world situations. (See Yelle for an extensive cataloging of applications since World War II).

The slope of the learning curve is, by definition, the fraction by which the price is reduced as the quantity doubles. There are two formulations of the learning curve commonly used - the cumulative average curve and the unit cost curve. As their names imply, the cumulative average curve computes the average cost of all units produced to a certain point whereas the unit curve computes the cost of the last unit produced at a specific point. Thus in the unit price formulation, a 90% learning curve means that the price of the 200th unit is 90% of the price of the 100th unit. Whereas in the cumulative average curve, a 90% learning curve means that the average cost for the 200 units is 90% of the average cost for 100 units.

The basic learning curve equation is:

(1) $Y_n = AX^b$

The variables Y and X have different values depending on which curve, unit or cumulative average, is being calculated. For both curves:

a = cost of first unit
b = the exponent of cost reduction defined as:

$$\frac{\ln \text{(slope of learning curve)}}{\ln(2)}$$

For the unit curve:

Y_n = the unit cost of the nth unit
X = the cumulative unit number (e.g., unit 100)

For the cumulative curve:

Y_n = the cumulative average cost of n items
X = the cumulative output (e.g., 100 units)

The definition chosen for the slope coefficient determines whether a cost analyst is using the unit or cumulative average curve. There is no priori basis for choosing between these two formulations; both are equally correct. The unit curve formulation is the one most commonly used. The cost analyst should chose which definition he will use based on 1) what form he wants his final results in and 2) the availability and form of required information. The cost analyst must be clear which definition he is using because the two formulations lead to significantly different results as the following example illustrates.

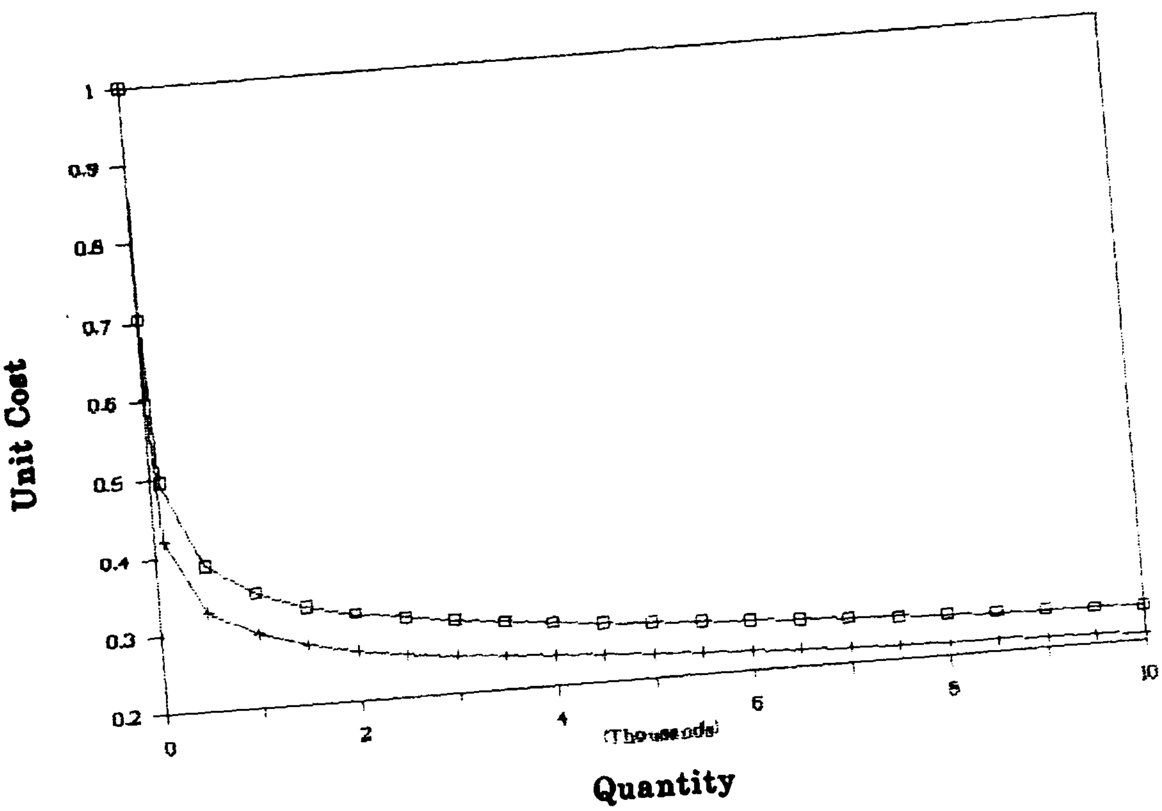
Assume 200 units are assumed to be produced, in two 100 unit lots. Then the values for total and average cost for each lot and accumulative units are seen in columns (1) and (2) in the following table.

	(1) Unit Curve	(2) Cumulative Average	(3) Cumulative Average
1st Unit Cost	1.00	1.00	1.00
Slope	90%	90%	91.91%
Cost of Unit 200	.45	.38	.46
Average Cost of 1 to 200	.52	.45	.46
Total Cost through 200	104.96	89.39	104.95
Total Cost of lot 101-200	46.96	39.73	47.86
Average Cost of lot 101-200	.47	.40	.48

Note that the total cost for 200 units are lower in the cumulative average case than in the unit formulation, 104.96 versus 89.39 a difference of 17%. A slope of 92% (91.91 more precisely) is required to have the total cost for the 200 units be the same. Column (3) shows these figures.

Figure 1 shows the relationship between unit price and quantity produced as calculated by a 90% learning curve for both the unit curve, A, and the cumulative average curve, B. Substantial price reductions are seen from even moderately sloped learning curve. Figure 1 does not use the more common semilog display in which the curves becomes straight lines. Such a display is visuallymisleading, suggesting that the percentage reduction in price is constant for each unit produced. Figure 1 shows that the percentage reduction for fixed increments, here 1000 units, falls.

Figure 1



The formulation of the learning curve expression seen in equation (1) is, as noted, the standard expression. However it is not ideally suited for the cost analysis of competition described in Chapter 6, because it does not easily allow computation of lot costs. Costs per lot are required to use present value analysis, an integral part of the cost benefit approach described in Chapter 6. While it is possible to compute the unit by unit cost and sum, it is easier to use integral calculus to derive a general formula to estimate lot costs. The integral utilizes the unit curve is:

$$C(N_1, N_0) = \int_{N_0}^{N_1} AX^B$$

which results in the the following expressions, which CAM uses to directly compute lot costs. (See Sherbrooke).

$$\text{(2) Lot Cost (units } N_0 \text{ to } N_1) = \frac{A}{b+1}\left[N_1^{b+1} - N_0^{b+1}\right]$$

where A and b are as defined for equation 1 and N_1 and N_0 are the beginning and ending quantities for the lot (e.g., units 200 to 101). The user of CAM must use the learning curve slope for the unit price and not for the cumulative average. Unfortunately, there is no expression which converts from the cumulative average slope to the unit slope.

Recent use of these curves have incorporated a yearly production rate adjustment. The argument is that prices improve faster if the (annual)

production rate is higher. This means that the 400th unit of an item has a different cost, given the learning curve slope, depending on its production rate produced at (e.g., 100 a year or 200 a year). CAM allows the user to input a rate coefficient, if desired. Choosing a value of 1.00 means that there is no rate effect.

The effects of changes in the production rate on cost are captured through use of an exponential function of lot size. We multiply equation 2 by this term to discover how unit cost changes when the production rate changes.

$$(3) \qquad \text{Lot Cost} = \frac{A}{b+1}[N_1^{b+1} - N_0^{b+1}]Q^c$$

where, Q = lot size $(N_1 - N_0 + 1)$

C = the exponent of the production rate defined as:

$$\frac{\log\ (.01 * \text{production rate})}{\log\ (2)}$$

Equations (2) and (3) use the section of the curve from 0 to 1 to approximate the cost of the first unit, from 1 to 2 to approximate the cost of the second unit, etc. This method of determining the approximating interval leads to each interval being to the left of the unit being estimated. If the curve is declining steeply, this type of interval approximation will tend to overstate cost. A more accurate method is to center the approximation around the unit being estimated. For example, the curve from 0.5 to 1.5

would be used to estimate the cost of the first unit. Equation (4) incorporates this technique and is the equation CAM uses.

$$(4) \qquad \text{Cost} = \frac{A}{b+1}[(N_1+.5)^{b+1} - (N_0+.5)^{b+1}]Q^c$$

Shift and Rotation

For competition to lower cost, there must be a movement of the basic learning curve. The analytical tool that has come to be used to estimate the impact of competition is "shift and rotation" of the price improvement curve. Figures 2 and 3 show how shift and rotation affect the basic curve shown in Figure 1. Figure 2 shows a 10% shift, and Figure 3 shows 5% rotation. The analysis underlying shift and rotation is that competition leads to both an immediate reduction in price--shift--and an increase in learning--rotation. Although the precise economic factors have not been fully articulated, the basic nature of the argument is clear. Shift is caused by immediate belt tightening, including lowered profit margins and reduction or reallocation of overhead. Rotation is caused by more effective management which leads to more efficient use of labor and materials. More precisely, management learns faster how to use labor and material more economically. Shift and rotation have differing effects on price reduction. It takes a relatively large shift to have the same cost impact as a small rotation. The cost benefit analysis used by CAM requires the user to specify percentage values for shift and rotation. However CAM does permit the bypassing of estimating shift and rotation to allow for the direct computation of the savings required to breakeven from competition.

Figure 2

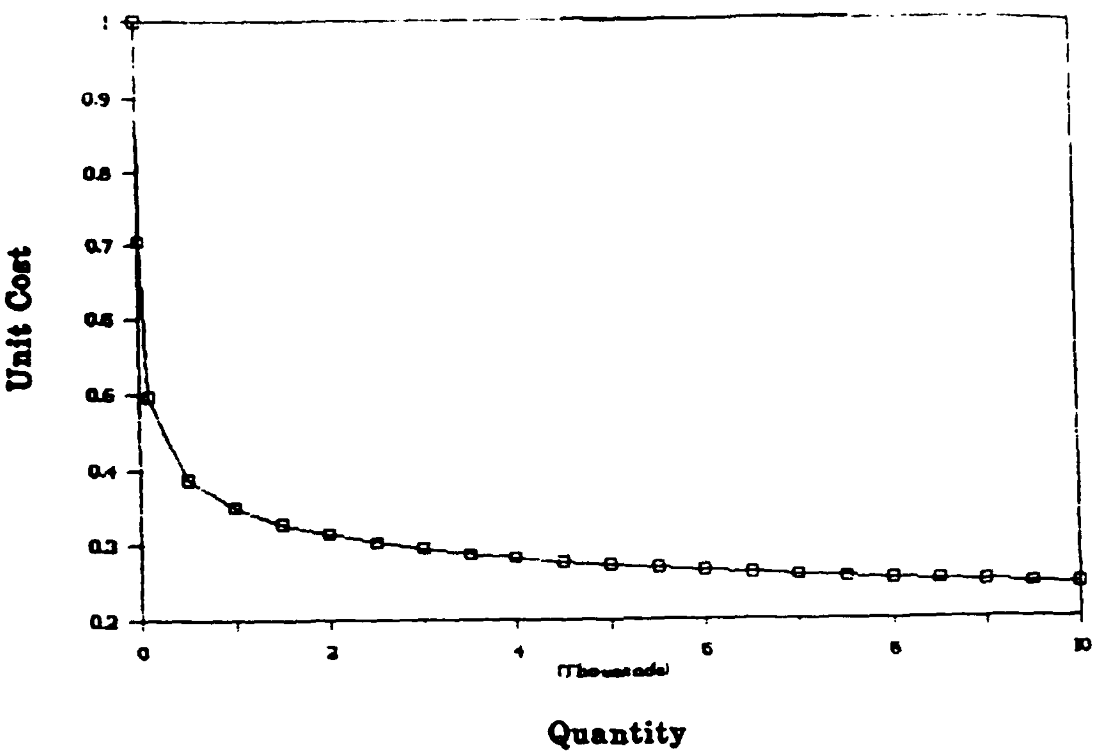
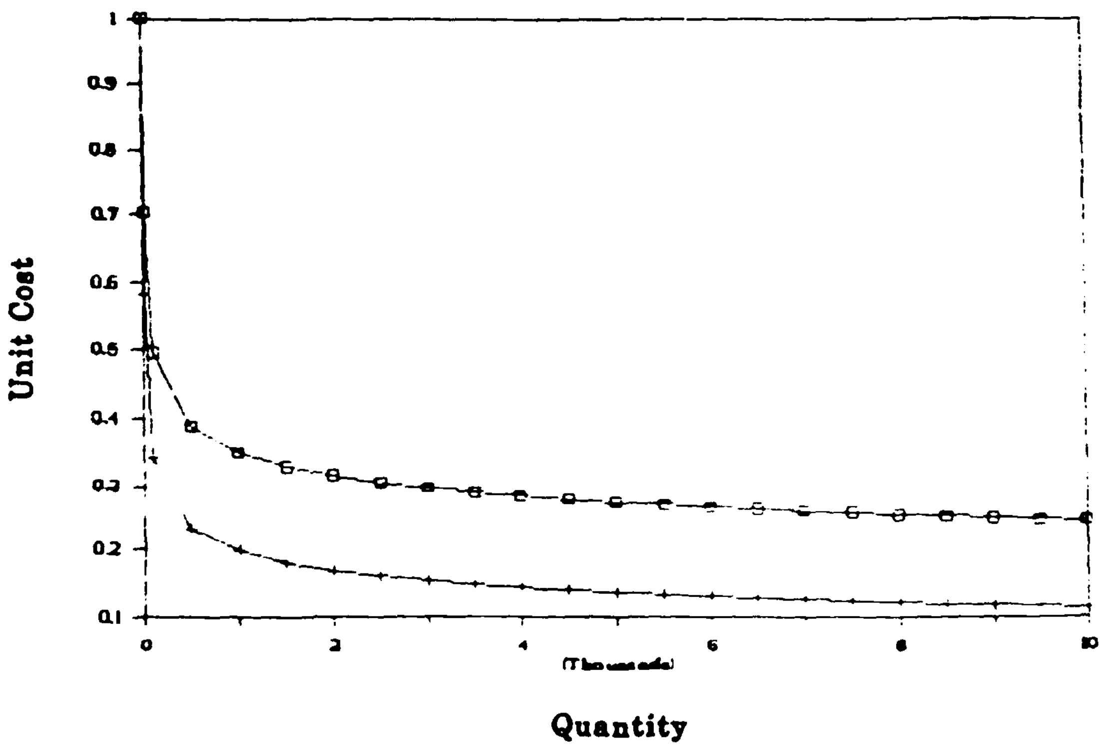


Figure 3



Current cost analysis application applies PICs to all components of cost – materials, including raw materials, finished parts, and fully assembled components purchased from subcontractors. Raw materials experience "learning" because the labor staff "learns" how to use material more efficiently, just as they learn to use labor more efficiently. Material that includes purchased items has a somewhat different relationship. Purchased items are by definition already assembled, thus the opportunity for learning is small. Any cost reductions that are observed, must come primarily from the prime driving a harder bargain with its suppliers. CAM only allows for the use of one learning curve for a project, which can be considered a composite curve including production labor, material and engineering labor. A different mix between labor and material is one reason for two competitors to have different sloped learning curves.

APPENDIX B

Economic Data for the Feasibility Test

The economic data we propose in the feasibility tests can be regarded as an indicator of the long term average cost behavior of an industry. It shows, by cost category, trends in industries, and by showing trends, it offers some capability for predicting future cost behavior. The data represents the average cost structure for the firms within a given industry, and it is important to note that the underlying cost structure for a specific firm will vary from the averages shown. The data then provide a measure of the size of the potential reductions in cost categories from which competitively-driven price reductions may be realized.

The Census of Manufacturers and the Annual Survey of Manufacturers

Every five years, the Department of Commerce takes a census of all manufacturers in the United States. This Census of Manufacturers collects data on, among other things, the total number of employees in a firm, total payroll, the number of production workers and their cost, the cost of materials, and the value of shipments. To get information between census years, Commerce does an Annual Survey of Manufacturers, which is a statistical sampling of manufacturers, to get the same data. The Census and the Annual Survey are required by law, and responses to them are quite good. Commerce publishes the data for both the Census and the Annual Survey. This data is the foundation for our analysis.

SIC (Standard Industrial Classification) Coding

The Census and Annual Survey data is collected by SIC code. The SIC is a 9 digit code which describes the primary activity of a plant (not a company) in the United States. Despite this definition, this code is not limited to describing the plant. A plant that performs several activities reports dollar values such as "Value of Shipments" or "Cost of Materials" under the SIC that describes the actual activity. This means that, by examining the reported data, we can tell how much money was spent on, for example, materials for the aircraft engine and engine parts industry in a given year. The data that we use for our analysis is available at the four digit level. The four digit level is easiest and probably most clear to use since several directly relevant extracts of data are published at this level, and since using more or fewer digits (using lower or higher levels) requires separating out double counted data.

Derivation of Data

In Appendix B we provide basic data arranged by SIC and by year within that SIC, for 22 industries which contribute heavily to the defense market. Data is provided at the four-digit SIC level, the same level that is used in publishing data.

There are seven cost categories used in our analysis which are taken directly from, or derived from the SIC data. These are:

1) Direct Labor (Production Line)
2) Material Costs
3) Overhead Costs
4) Indirect Labor Costs
5) Loaded Direct Wages
6) Total Labor
7) Sales

Total Labor, Direct Labor, and Material Costs and Sales come directly from Commerce data as the table below shows:

Reported to Commerce	**Can Be Defined As**
All Employees/Payroll	Total Labor Costs
Production Workers/Payroll	Direct Labor Costs
Cost of Materials	Materials Costs
Value of Shipments	Sales

The remaining three categories are derived as follows:

Indirect Labor = Total Labor - Direct Labor
Overhead = Sales - (Direct Labor + Materials)
Loaded Direct Wages = Direct Labor + Overhead

Finally, data for the first six categories can be expressed as a percentage of the seventh category, sales.

Selected Industry Data Sets

SIC 3313 - Electrometallurgical Products

SIC 3441 - Fabricated Structural Metal

SIC 3511 - Turbines, Turbine Generator Sets

SIC 3542 - Machine Tools, Metal Forming

SIC 3544 - Special Tools, Dies, Jigs, Etc.

SIC 3561 - Pumps and Pumping Equipment

SIC 3563 - Air and Gas Compressurs

SIC 3566 - Speed Changers, Drivers, Gears

SIC 3573 - Electronic Computing Equipment

SIC 3592 - Carburators, Pistons, Rings and Valves

SIC 3613 - Switchgear and Switchboard Apparatus

SIC 3621 - Motors and Generators

SIC 3622 - Industrial Controls

SIC 3662 - Radio, TV Communication Equipment

SIC 3674 - Semiconductors, Related Devices

SIC 3694 - Engine Electrical Equipment

SIC 3721 - Aircraft

SIC 3724 - Aircraft Engines and Engine Parts

SIC 3728 - Aircraft Equipment, N.E.C.

SIC 3761 - Guided Missiles, Space Vehicles

SIC 3764 - Space Propulsion Units, Parts

SIC 3769 - Space Vehicle Equipment, N.E.C.

COST FACTORS AS A PERCENT OF SALES

SIC: 3313 ELECTROMETALLURGICAL PRODUCTS

YEAR	AS A PERCENT OF SALES					
	DIRECT LABOR	MATERIAL COSTS	OVERHEAD COSTS	INDIRECT LABOR COSTS	LOADED DIRECT WAGES	TOTAL LABOR
1983	10.73	64.80	24.47	4.53	35.20	15.26
1982	12.15	69.77	18.08	5.37	30.23	17.51
1981	10.67	73.67	15.66	3.79	26.33	14.46
1980	10.25	68.45	21.30	3.36	31.55	13.61
1979	10.02	67.50	22.48	2.73	32.50	12.75
1978	10.02	71.15	18.83	3.15	28.85	13.17
1977	11.17	73.79	15.04	3.76	26.21	14.93
1976	10.29	69.47	20.23	3.63	30.53	13.92
1975	10.08	65.55	24.37	3.36	34.45	13.45
1974	8.87	57.10	34.03	2.51	42.90	11.38
1973	11.48	63.04	25.48	3.43	36.96	14.90
1972	13.07	60.80	26.13	3.99	39.20	17.06
1971	12.79	61.44	25.77	4.14	38.56	16.94
1970	13.87	63.78	22.35	4.05	36.22	17.92
1969	11.66	61.06	27.27	3.43	38.94	15.09
1968	13.14	60.78	26.08	4.11	39.22	17.25
1967	12.61	61.97	25.43	4.27	38.03	16.88
1966	11.05	59.96	28.99	3.94	40.04	14.99
1965	12.32	56.78	30.90	3.76	43.22	16.08
1964	13.50	61.56	24.94	3.89	38.44	17.39
1963	13.35	59.69	26.96	4.71	40.31	18.06
1962	13.21	60.10	26.68	5.44	39.90	18.65
1961	12.25	58.00	29.75	5.25	42.00	17.50

COST FACTORS AS A PERCENT OF SALES

SIC: 3441 FABRICATED STRUCTURAL METAL

YEAR	AS A PERCENT OF SALES					
	DIRECT LABOR	MATERIAL COSTS	OVERHEAD COSTS	INDIRECT LABOR	LOADED DIRECT	TOTAL LABOR
1983	14.70	59.81	25.49	8.44	40.19	23.14
1982	14.66	56.67	28.67	7.84	43.33	22.50
1981	15.02	59.33	25.65	7.72	40.67	22.74
1980	14.80	58.00	27.20	7.78	42.00	22.58
1979	14.63	58.71	26.66	7.70	41.29	22.32
1978	15.23	57.29	27.47	8.17	42.71	23.40
1977	15.20	54.82	29.97	8.66	45.18	23.87
1976	15.24	53.62	31.14	8.26	46.38	23.50
1975	14.94	52.72	32.34	7.86	47.28	22.80
1974	14.81	57.55	27.64	8.04	42.45	22.85
1973	15.94	56.16	27.90	8.47	43.84	24.42
1972	16.20	56.12	27.68	8.70	43.88	24.90
1971	16.48	54.15	29.37	8.48	45.85	24.96
1970	17.33	54.36	28.30	9.08	45.64	26.41
1969	17.83	54.16	28.01	9.23	45.84	27.06
1968	17.31	54.86	27.83	9.22	45.14	26.53
1967	17.18	54.75	28.07	8.89	45.25	26.08
1966	17.06	57.61	25.33	8.49	42.39	25.56
1965	17.49	58.62	23.89	8.86	41.38	26.35
1964	17.92	59.72	22.35	8.87	40.28	26.79
1963	18.27	59.55	22.18	9.24	40.45	27.51
1962	17.60	59.39	23.01	9.36	40.61	26.96
1961	17.75	57.22	25.03	9.54	42.78	27.29

COST FACTORS AS A PERCENT OF SALES

SIC: 3511 TURBINES, TURBINE GENERATOR SETS

YEAR	AS A PERCENT OF SALES					
	DIRECT LABOR	MATERIAL COSTS	OVERHEAD COSTS	INDIRECT LABOR	LOADED DIRECT	TOTAL LABOR
1983	11.38	39.62	49.00	11.85	60.38	23.23
1982	11.75	41.21	47.03	11.94	58.79	23.69
1981	11.49	43.51	45.01	12.48	56.49	23.96
1980	11.77	43.00	45.24	11.77	57.00	23.54
1979	12.31	41.71	45.98	12.37	58.29	24.68
1978	13.83	44.49	41.68	12.92	55.51	26.75
1977	13.50	45.54	40.97	12.47	54.46	25.97
1976	12.63	47.68	39.69	11.67	52.32	24.30
1975	12.94	49.96	37.10	11.19	50.04	24.13
1974	13.65	48.21	38.13	11.39	51.79	25.04
1973	13.5	44.96	41.47	11.97	55.04	25.54
1972	13.66	44.22	42.12	11.42	55.78	25.08
1971	15.68	55.09	29.23	11.13	44.91	26.81
1970	15.63	52.93	31.43	11.33	47.07	26.97
1969	15.62	45.72	38.66	12.01	54.28	27.63
1968	16.82	50.62	32.56	11.91	49.38	28.73
1967	18.79	45.64	35.57	11.79	54.36	30.58
1966	22.26	48.90	28.84	12.34	51.10	34.60
1965	22.92	44.21	32.87	12.97	55.79	35.89
1964	22.01	39.73	38.26	13.42	60.27	35.44
1963	23.05	39.45	37.50	15.58	60.55	38.64
1962	22.04	38.45	39.51	15.35	61.55	37.39
1961	18.68	36.06	45.26	15.66	63.94	34.34

COST FACTORS AS A PERCENT OF SALES

SIC: 3542 MACHINE TOOLS, METAL-FORMING

YEAR	AS A PERCENT OF SALES					
	DIRECT LABOR	MATERIAL COSTS	OVERHEAD COSTS	INDIRECT LABOR	LOADED DIRECT	TOTAL LABOR
1983	17.16	39.84	42.99	14.10	60.16	31.26
1982	17.14	40.24	42.62	13.51	59.76	30.65
1981	18.25	41.03	40.72	12.50	58.97	30.75
1980	17.86	41.02	41.13	11.47	58.98	29.32
1979	18.33	41.29	40.38	10.88	58.71	29.21
1978	18.52	42.17	39.31	11.93	57.83	30.45
1977	19.36	39.26	41.38	12.56	60.74	31.92
1976	19.98	40.52	39.50	11.48	59.48	31.47
1975	18.79	43.63	37.58	12.20	56.37	30.98
1974	25.66	45.95	28.39	8.10	54.05	33.76
1973	23.14	41.87	34.99	13.43	58.13	36.57
1972	23.56	40.95	35.49	14.51	59.05	38.07
1971	21.41	41.62	36.98	14.82	58.38	36.23
1970	22.81	42.40	34.79	13.40	57.60	36.21
1969	23.69	39.94	36.36	13.64	60.06	37.33
1968	21.87	37.60	40.53	12.40	62.40	34.26
1967	23.11	41.32	35.57	11.90	58.68	35.01
1966	22.53	42.86	34.62	11.13	57.14	33.65
1965	23.84	43.57	32.59	11.49	56.43	35.33
1964	24.16	39.41	36.44	11.49	60.59	35.64
1963	24.26	37.41	38.32	12.47	62.59	36.73
1962	24.55	40.40	35.04	13.84	59.60	38.39
1961	24.40	42.27	33.33	13.77	57.73	38.16

COST FACTORS AS A PERCENT OF SALES

SIC: 3544 SPECIAL DUES, TOOLS, JIGS, ETC.

YEAR	AS A PERCENT OF SALES					
	DIRECT LABOR	MATERIAL COSTS	OVERHEAD COSTS	INDIRECT LABOR	LOADED DIRECT	TOTAL LABOR
1983	31.31	28.94	39.75	11.88	71.06	43.19
1982	31.35	28.56	40.09	11.31	71.44	42.66
1981	30.43	30.09	39.48	11.59	69.91	42.02
1980	30.89	29.77	39.34	11.54	70.23	42.43
1979	30.77	30.13	39.09	11.04	69.87	41.81
1978	30.97	31.06	37.97	11.49	68.94	42.46
1977	32.32	30.01	37.67	11.42	69.99	43.74
1976	34.09	27.87	38.04	10.96	72.13	45.05
1975	33.68	26.93	39.39	11.33	73.07	45.01
1974	33.67	27.58	38.75	10.48	72.42	44.15
1973	34.12	26.71	39.17	10.75	73.29	44.87
1972	34.98	26.82	38.20	11.13	73.18	46.11
1971	40.37	27.41	32.22	7.64	72.59	48.01
1970	35.37	26.63	38.00	11.25	73.37	46.62
1969	36.98	26.34	36.68	11.26	73.66	48.24
1968	36.42	25.66	37.92	10.67	74.34	47.08
1967	36.33	26.25	37.42	10.58	73.75	46.91
1966	35.75	26.74	37.51	10.60	73.26	46.35
1965	37.19	27.95	34.86	10.71	72.05	47.91
1964	37.05	25.65	37.30	10.18	74.35	47.23
1963	39.09	26.85	34.05	10.08	73.15	49.17
1962	37.16	26.48	36.36	10.35	73.52	47.51
1961	38.27	25.96	35.77	12.06	74.04	50.33

COST FACTORS AS A PERCENT OF SALES

SIC: 3561 PUMPS AND PUMPING EQUIPMENT

YEAR	---------------- AS A PERCENT OF SALES ----------------					
	DIRECT LABOR	MATERIAL COSTS	OVERHEAD COSTS	INDIRECT LABOR	LOADED DIRECT	TOTAL LABOR
1983	12.55	42.59	44.86	12.59	57.41	25.14
1982	12.46	44.24	43.30	11.50	55.76	23.96
1981	12.52	44.99	42.49	10.29	55.01	22.81
1980	13.83	59.72	26.45	10.90	40.28	24.73
1979	13.54	43.99	42.47	10.30	56.01	23.84
1978	13.79	43.25	42.95	10.54	56.75	24.34
1977	13.43	45.60	40.96	10.44	54.40	23.87
1976	13.50	45.81	40.70	10.84	54.19	24.34
1975	9.58	47.23	43.19	14.96	52.77	24.54
1974	10.26	48.72	41.03	16.27	51.28	26.53
1973	10.95	45.71	43.35	16.17	54.29	27.11
1972	16.80	45.55	37.65	10.86	54.45	27.66
1971	14.65	46.17	39.18	12.56	53.83	27.21
1970	15.41	45.53	39.07	12.18	54.47	27.59
1969	15.25	45.90	38.85	11.60	54.10	26.84
1968	14.91	45.81	39.27	11.82	54.19	26.74
1967	15.18	46.76	38.06	11.64	53.24	26.82
1966	15.67	46.82	37.52	11.25	53.18	26.92
1965	15.90	46.91	37.19	11.69	53.09	27.59
1964	16.16	45.79	38.05	11.99	54.21	28.15
1963	15.86	46.51	37.63	12.05	53.49	27.91
1962	16.50	46.41	37.09	13.03	53.59	29.53
1961	15.93	46.26	37.80	12.85	53.74	28.78

COST FACTORS AS A PERCENT OF SALES

SIC: 3563 AIR AND GAS COMPRESSORS

YEAR	AS A PERCENT OF SALES					
	DIRECT LABOR	MATERIAL COSTS	OVERHEAD COSTS	INDIRECT LABOR	LOADED DIRECT	TOTAL LABOR
1983	10.66	49.50	39.84	19.38	50.50	30.04
1982	10.52	51.93	37.55	11.16	48.07	21.68
1981	11.52	50.17	38.30	10.52	49.83	22.04
1980	11.64	49.16	39.20	10.16	50.84	21.80
1979	11.98	46.88	41.14	9.95	53.12	21.93
1978	12.81	46.41	40.78	10.08	53.59	22.89
1977	12.28	45.91	41.81	10.16	54.09	22.45
1976	11.28	49.80	38.92	9.33	50.20	20.61
1975	12.06	48.97	38.97	10.67	51.03	22.73
1974	14.16	50.62	35.22	11.62	49.38	25.78
1973	14.23	48.62	37.15	12.35	51.38	26.58
1972	13.75	46.27	39.98	12.70	53.73	26.46
1971						
1970						
1969						
1968						
1967						
1966						
1965						
1964						
1963						
1962						
1961						

NOTE: IF PART OR ALL OF A LINE IS BLANK, DATA IS NOT AVAILABLE

COST FACTORS AS A PERCENT OF SALES

SIC: 3566 SPEED CHANGERS, DRIVES, GEARS

YEAR	AS A PERCENT OF SALES					
	DIRECT LABOR	MATERIAL COSTS	OVERHEAD COSTS	INDIRECT LABOR	LOADED DIRECT	TOTAL LABOR
1983	18.11	34.90	46.99	13.86	65.10	31.96
1982	18.26	33.99	47.75	12.52	66.01	30.78
1981	18.33	37.67	43.99	11.29	62.33	29.63
1980	18.28	37.24	44.48	11.44	62.76	29.71
1979	18.77	37.59	43.64	10.85	62.41	29.61
1978	18.80	36.11	45.10	11.66	63.89	30.46
1977	18.58	35.19	46.24	11.29	64.81	29.87
1976	18.20	35.41	46.38	10.06	64.59	28.26
1975	18.91	38.35	42.73	10.16	61.65	29.07
1974	20.69	38.67	40.64	11.12	61.33	31.81
1973	21.83	38.14	40.03	12.42	61.86	34.25
1972	21.80	36.49	41.71	13.59	63.51	35.39

COST FACTORS AS A PERCENT OF SALES

SIC: 3573 ELECTRONIC COMPUTING EQUIPMENT

YEAR	DIRECT LABOR	MATERIAL COSTS	OVERHEAD COSTS	INDIRECT LABOR	LOADED DIRECT	TOTAL LABOR
	AS A PERCENT OF SALES					
1983	6.42	51.02	42.56	15.26	48.98	21.68
1982	6.37	47.57	46.06	15.51	52.43	21.88
1981	6.61	46.12	47.27	15.09	53.88	21.70
1980	7.05	48.08	44.87	15.20	51.92	22.25
1979	7.20	46.52	46.28	15.05	53.48	22.25
1978	7.65	45.41	46.94	15.38	54.59	23.03
1977	7.64	44.12	48.24	15.68	55.88	23.32
1976	6.81	42.16	51.03	16.79	57.84	23.59
1975	8.52	43.25	48.23	17.02	56.75	25.54
1974	8.72	45.65	45.64	15.64	54.35	24.36
1973	8.92	46.89	44.19	16.53	53.11	25.45
1972	7.57	45.12	47.31	19.03	54.88	26.60
1971	11.29	43.39	45.32	18.34	56.61	29.63
1970	11.50	44.76	43.74	16.06	55.24	27.56
1969	11.77	47.71	40.52	14.64	52.29	26.41
1968	11.77	44.96	43.27	13.49	55.04	25.26
1967	11.92	46.30	41.77	12.59	53.70	24.51
1966	11.17	56.61	32.22	11.13	43.39	22.30
1965	13.69	53.49	32.82	13.37	46.51	27.06
1964	13.15	52.11	34.74	12.62	47.89	25.77
1963	13.51	52.79	33.70	12.16	47.21	25.67
1962						
1961						

NOTE: IF PART OR ALL OF A LINE IS BLANK, DATA IS NOT AVAILABLE

COST FACTORS AS A PERCENT OF SALES

SIC: 3592 CARBURATORS, PISTONS, RINGS, VALVES

YEAR	AS A PERCENT OF SALES					
	DIRECT LABOR	MATERIAL COSTS	OVERHEAD COSTS	INDIRECT LABOR	LOADED DIRECT	TOTAL LABOR
1983	21.89	37.34	40.76	8.13	62.66	30.02
1982	22.11	35.78	42.11	8.99	64.22	31.10
1981	24.17	35.95	39.89	8.35	64.05	32.52
1980	25.23	36.65	38.12	8.97	63.35	34.20
1979	26.47	35.03	38.50	8.30	64.97	34.77
1978	26.35	35.05	38.60	8.27	64.95	34.62
1977	27.77	35.97	36.26	8.57	64.03	36.33
1976	27.63	35.35	37.02	8.44	64.65	36.07
1975	27.06	36.17	36.77	10.01	63.83	37.07
1974	29.07	37.77	33.16	9.72	62.23	38.79
1973	28.00	35.36	36.64	8.45	64.64	36.44
1972	27.82	35.22	36.96	9.27	64.78	37.10
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NOTE: IF PART OR ALL OF A LINE IS BLANK, DATA IS NOT AVAILABLE

COST FACTORS AS A PERCENT OF SALES

SIC: 3613 SWITCHGEAR AND SWITCHBOARD APPARATUS

YEAR	AS A PERCENT OF SALES					
	DIRECT LABOR	MATERIAL COSTS	OVERHEAD COSTS	INDIRECT LABOR	LOADED DIRECT	TOTAL LABOR
1983	13.68	38.81	47.51	10.51	61.19	24.19
1982	13.84	37.64	48.52	10.46	62.36	24.30
1981	14.51	37.68	47.81	10.01	62.32	24.52
1980	14.07	40.37	45.56	9.57	59.63	23.63
1979	15.35	40.11	44.54	9.30	59.89	24.65
1978	15.34	40.64	44.02	9.35	59.36	24.69
1977	15.73	40.38	43.89	9.57	59.62	25.30
1976	16.06	39.81	44.12	10.22	60.19	26.29
1975	16.12	39.31	44.57	10.52	60.69	26.64
1974	17.80	41.29	40.91	10.08	58.71	27.88
1973	18.16	40.41	41.43	10.44	59.59	28.59
1972	18.30	39.76	41.94	10.78	60.24	29.08
1971	17.67	49.80	32.53	10.66	50.20	28.33
1970	18.18	39.64	42.18	10.76	60.36	28.93
1969	17.52	38.92	43.56	10.53	61.08	28.06
1968	17.32	39.84	42.84	10.61	60.16	27.92
1967	18.05	39.64	42.31	10.83	60.36	28.88
1966	18.01	39.25	42.74	10.97	60.75	28.99
1965	18.17	39.49	42.34	11.55	60.51	29.72
1964	18.47	41.70	39.83	12.77	58.30	31.23
1963	18.74	41.32	39.95	12.25	58.68	30.99
1962	19.13	41.43	39.44	13.00	58.57	32.13
1961	19.06	41.39	39.56	13.28	58.61	32.34

COST FACTORS AS A PERCENT OF SALES

SIC: 3621 MOTORS AND GENERATORS

YEAR	AS A PERCENT OF SALES					
	DIRECT LABOR	MATERIAL COSTS	OVERHEAD COSTS	INDIRECT LABOR	LOADED DIRECT	TOTAL LABOR
1983	16.73	44.12	39.15	9.18	55.88	25.91
1982	16.24	41.70	42.06	9.28	58.30	25.52
1981	17.24	43.49	39.27	8.23	56.51	25.47
1980	17.49	44.32	38.19	8.69	55.68	26.19
1979	18.10	44.55	37.34	8.29	55.45	26.40
1978	18.16	44.00	37.83	8.25	56.00	26.42
1977	17.99	42.97	39.04	8.41	57.03	26.40
1976	18.57	42.98	38.45	8.51	57.02	27.07
1975	18.08	43.43	38.49	9.01	56.57	27.09
1974	19.33	45.91	34.76	8.99	54.09	28.32
1973	21.08	43.33	35.60	9.07	56.67	30.14
1972	20.59	41.93	37.48	9.78	58.07	30.37
1971	20.82	42.74	36.44	10.82	57.26	31.64
1970	22.18	42.87	34.95	10.75	57.13	32.93
1969	21.74	41.97	36.29	10.15	58.03	31.89
1968	21.47	41.30	37.23	10.55	58.70	32.02
1967	21.40	40.72	37.89	10.45	59.28	31.85
1966	21.58	42.33	36.09	10.31	57.67	31.89
1965	21.92	42.51	35.57	10.47	57.49	32.39
1964	21.59	40.88	37.53	11.92	59.12	33.52
1963	22.16	41.81	36.02	11.93	58.19	34.09
1962	21.83	42.10	36.07	12.91	57.90	34.74
1961	22.27	40.91	36.82	14.17	59.09	36.44

COST FACTORS AS A PERCENT OF SALES

SIC: 3622 INDUSTRIAL CONTROLS

YEAR	AS A PERCENT OF SALES					
	DIRECT LABOR	MATERIAL COSTS	OVERHEAD COSTS	INDIRECT LABOR	LOADED DIRECT	TOTAL LABOR
1983	12.71	24.00	63.29	17.15	76.00	29.86
1982	12.93	38.47	48.60	16.67	61.53	29.60
1981	13.54	38.01	48.45	14.48	61.99	28.03
1980	14.25	39.35	46.40	13.60	60.65	27.85
1979	15.14	38.19	46.68	12.86	61.81	28.00
1978	14.60	38.34	47.06	13.57	61.66	28.17
1977	15.15	38.29	46.56	13.80	61.71	28.95
1976	16.20	39.75	44.05	13.11	60.25	29.31
1975	16.54	39.61	43.84	13.82	60.39	30.36
1974	17.96	40.33	41.71	12.52	59.67	30.48
1973	17.80	39.83	42.37	14.34	60.17	32.14
1972	18.14	39.64	42.21	14.64	60.36	32.79
1971	18.36	34.84	46.80	15.63	65.16	33.99
1970	18.27	34.84	46.88	15.46	65.16	33.73
1969	19.26	34.57	46.17	14.83	65.43	34.09
1968	18.55	34.88	46.57	14.81	65.12	33.36
1967	19.13	35.27	45.60	12.69	64.73	31.82
1966	18.68	35.08	46.23	12.30	64.92	30.98
1965	19.27	33.69	47.04	12.53	66.31	31.80
1964	18.96	33.56	47.48	13.10	66.44	32.06
1963	19.26	32.05	48.69	13.87	67.95	33.13
1962	19.90	31.53	48.57	14.67	68.47	34.57
1961	19.34	31.20	49.45	15.69	68.80	35.04

AD-A183 883 COMPETITION ANALYSIS MODEL (CAM) ANALYSIS GUIDE VOLUME 1(U) ADMINISTRATIVE SCIENCES CORP ARLINGTON VA 12 JUN 87 ASC-R-161-VOL-1 BRMC-85-5129-1 2/2

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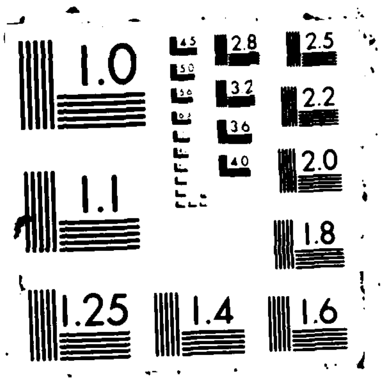
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COST FACTORS AS A PERCENT OF SALES

SIC: 3662 RADIO, TV, COMMUNICATION EQUIPMENT

YEAR	AS A PERCENT OF SALES					
	DIRECT LABOR	MATERIAL COSTS	OVERHEAD COSTS	INDIRECT LABOR	LOADED DIRECT	TOTAL LABOR
1983	12.40	33.55	54.05	21.33	66.45	33.73
1982	12.81	36.45	50.74	20.36	63.55	33.17
1981	13.72	36.19	50.09	20.54	63.81	34.26
1980	13.76	35.89	50.35	19.92	64.11	33.68
1979	14.04	36.65	49.31	20.72	63.35	34.76
1978	14.99	35.41	49.59	21.12	64.59	36.11
1977	14.13	34.76	51.11	20.64	65.24	34.77
1976	13.69	35.82	50.49	21.16	64.18	34.85
1975	14.06	37.12	48.82	21.49	62.88	35.56
1974	14.78	36.38	48.84	22.40	63.62	37.18
1973	15.47	35.74	48.79	23.25	64.26	38.72
1972	15.84	36.52	47.64	23.42	63.48	39.27
1971	14.85	35.19	49.97	24.67	64.81	39.52
1970	15.61	35.04	49.35	25.11	64.96	40.72
1969	16.06	36.13	47.81	24.94	63.87	40.99
1968	16.57	38.84	44.59	23.48	61.16	40.05
1967	17.72	40.12	42.16	23.99	59.88	41.71
1966	17.66	40.09	42.25	23.15	59.91	40.82
1965	17.18	37.42	45.39	23.83	62.58	41.01
1964	17.97	35.61	46.42	22.57	64.39	40.54
1963	17.23	39.50	43.27	22.52	60.50	39.74
1962	18.13	43.52	38.36	20.53	56.48	38.66
1961	16.12	45.38	38.50	21.94	54.62	38.06

COST FACTORS AS A PERCENT OF SALES

SIC: 3674 SEMICONDUCTORS, RELATED DEVICES

YEAR	AS A PERCENT OF SALES					
	DIRECT LABOR	MATERIAL COSTS	OVERHEAD COSTS	INDIRECT LABOR	LOADED DIRECT	TOTAL LABOR
1983	10.44	33.06	56.51	20.10	66.94	30.54
1982	10.56	33.76	55.68	19.89	66.24	30.45
1981	11.21	34.34	54.45	17.89	65.66	29.10
1980	11.22	36.34	52.44	16.74	63.66	27.96
1979	11.32	35.79	52.88	15.89	64.21	27.[illegible]
1978	12.59	35.90	51.52	16.92	64.10	29.51
1977	12.59	37.78	49.63	17.49	62.22	30.08
1976	11.85	36.30	51.86	18.80	63.70	30.64
1975	13.76	33.38	52.85	22.86	66.62	36.62
1974	14.54	40.79	44.67	19.54	59.21	34.08
1973	15.16	37.31	47.53	17.76	62.69	32.92
1972	15.53	27.02	57.45	19.70	72.98	35.23
1971	18.75	31.38	49.88	22.38	68.63	41.13
1970	22.98	35.51	41.51	21.25	64.49	44.24
1969	24.73	34.65	40.62	20.15	65.35	44.88
1968	25.82	30.83	43.36	19.97	69.17	45.79
1967	26.91	29.62	43.47	20.86	70.38	47.77
1966	24.38	28.20	47.42	19.57	71.80	43.95
1965	25.00	26.54	48.46	18.97	73.46	43.97
1964	24.58	28.63	46.79	21.09	71.37	45.67
1963	24.56	28.92	46.51	22.09	71.08	46.66
1962						
1961						

NOTE: IF PART OR ALL OF A LINE IS BLANK, DATA IS NOT AVAILABLE

COST FACTORS AS A PERCENT OF SALES

SIC: 3694 ENGINE ELECTRICAL EQUIPMENT

YEAR	AS A PERCENT OF SALES					
	DIRECT LABOR	MATERIAL COSTS	OVERHEAD COSTS	INDIRECT LABOR	LOADED DIRECT	TOTAL LABOR
1983	15.88	44.49	39.62	6.43	55.51	22.32
1982	15.44	45.67	38.89	8.26	54.33	23.70
1981	16.97	47.75	35.27	8.16	52.25	25.13
1980	17.40	48.89	33.71	7.95	51.11	25.35
1979	18.31	46.56	35.14	6.86	53.44	25.17
1978	19.23	45.63	35.14	6.66	54.37	25.89
1977	19.44	45.16	35.40	6.55	54.84	25.99
1976	19.10	44.35	36.55	6.23	55.65	25.32
1975	19.52	45.10	35.38	7.08	54.90	26.61
1974	22.19	47.57	30.23	7.12	52.43	29.31
1973	22.83	43.70	33.46	6.91	56.30	29.75
1972	22.21	42.01	35.77	6.83	57.99	29.04
1971	20.14	43.81	36.05	6.75	56.19	26.89
1970	20.32	44.82	34.86	7.41	55.18	27.73
1969	20.65	42.75	36.60	7.21	57.25	27.86
1968	21.37	42.02	36.61	7.19	57.98	28.56
1967	21.03	43.88	35.09	7.33	56.12	28.35
1966	20.25	46.24	33.51	6.70	53.76	26.95
1965	20.11	44.79	35.10	6.70	55.21	26.82
1964	19.98	43.30	36.72	7.24	56.70	27.21
1963	20.42	44.17	35.41	7.33	55.83	27.75
1962	21.33	42.21	36.46	8.84	57.79	30.17
1961	20.63	40.60	38.77	10.31	59.40	30.94

COST FACTORS AS A PERCENT OF SALES

SIC: 3721 AIRCRAFT

YEAR	AS A PERCENT OF SALES					
	DIRECT LABOR	MATERIAL COSTS	OVERHEAD COSTS	INDIRECT LABOR COSTS	LOADED DIRECT WAGES	TOTAL LABOR
1983	10.64	48.85	40.51	14.13	51.15	24.78
1982	12.56	56.04	31.40	15.07	43.96	27.63
1981	12.12	52.47	35.41	14.54	47.53	26.67
1980	11.74	54.67	33.59	13.15	45.33	24.89
1979	12.46	54.98	32.56	12.95	45.02	25.41
1978	13.16	51.34	35.50	14.73	48.66	27.89
1977	11.90	45.46	42.65	14.90	54.54	26.80
1976	12.17	45.47	42.36	14.38	54.53	26.55
1975	12.44	45.77	41.79	14.98	54.23	27.42
1974	13.44	44.44	42.12	14.83	55.56	28.27
1973	13.62	44.07	42.31	15.06	55.93	28.68
1972	15.17	45.83	39.00	17.48	54.17	32.66
1971	13.16	46.96	39.88	16.24	53.04	29.40
1970	14.47	47.55	37.98	17.04	52.45	31.51
1969	14.87	46.27	38.85	17.81	53.73	32.68
1968	14.80	49.65	35.55	15.22	50.35	30.02
1967	16.31	50.84	32.85	15.90	49.16	32.21
1966	16.98	38.07	44.96	18.82	61.93	35.80
1965	16.35	47.83	35.83	18.72	52.17	35.07
1964	18.54	47.42	34.04	16.83	52.58	35.37
1963	17.37	43.91	38.72	20.14	56.09	37.50
1962	18.22	45.79	35.98	21.56	54.21	39.78
1961	17.07	49.22	33.72	19.70	50.78	36.77

COST FACTORS AS A PERCENT OF SALES

SIC: 3724 AIRCRAFT ENGINES, ENGINE PARTS

YEAR	AS A PERCENT OF SALES					
	DIRECT LABOR	MATERIAL COSTS	OVERHEAD COSTS	INDIRECT LABOR COSTS	LOADED DIRECT WAGES	TOTAL LABOR
1983	12.88	43.97	43.15	12.25	56.03	25.13
1982	13.16	45.36	41.48	12.49	54.64	25.65
1981	13.70	50.67	35.62	12.16	49.33	25.86
1980	14.33	47.67	37.99	12.43	52.33	26.76
1979	15.68	45.19	39.13	13.49	54.81	29.17
1978	15.89	46.72	37.39	14.81	53.28	30.69
1977	15.47	44.04	40.50	15.45	55.96	30.92
1976	13.99	43.98	42.03	14.94	56.02	28.93
1975	15.23	45.66	39.11	15.28	54.34	30.51
1974	16.41	43.19	40.40	16.43	56.81	32.84
1973	16.41	43.07	40.52	16.66	56.93	33.07
1972	16.57	47.86	35.58	23.46	52.14	40.03
1971	14.88	46.68	38.44	19.52	53.32	34.39
1970	14.86	44.86	40.28	17.66	55.14	32.52
1969	15.40	46.92	37.68	18.28	53.08	33.69
1968	15.81	46.81	37.38	17.31	53.19	33.12
1967	16.54	45.20	38.26	17.07	54.80	33.61
1966	18.10	44.61	37.29	18.58	55.39	36.68
1965	17.04	43.14	39.81	19.74	56.86	36.78
1964	16.34	43.31	40.35	20.76	56.69	37.10
1963	16.97	45.64	37.39	19.33	54.36	36.30
1962	17.65	46.09	36.26	18.72	53.91	36.37
1961	17.61	46.48	35.90	18.26	53.52	35.87

COST FACTORS AS A PERCENT OF SALES

SIC: 3728 AIRCRAFT EQUIPMENT,NEC.

YEAR	AS A PERCENT OF SALES					
	DIRECT LABOR	MATERIAL COSTS	OVERHEAD COSTS	INDIRECT LABOR	LOADED DIRECT	TOTAL LABOR
1983	15.15	40.37	44.48	17.07	59.63	32.22
1982	16.25	39.08	44.67	17.44	60.92	33.69
1981	19.61	39.16	41.22	17.06	60.84	36.67
1980	19.47	43.52	37.01	17.48	56.48	36.95
1979	19.39	41.68	38.93	17.15	58.32	36.54
1978	18.37	39.54	42.09	18.87	60.46	37.25
1977	17.39	36.71	45.89	18.42	63.29	35.81
1976	19.57	34.18	46.25	13.84	65.82	33.41
1975	20.74	37.26	42.00	13.72	62.74	34.47
1974	22.01	39.46	38.53	13.64	60.54	35.65
1973	21.78	38.02	40.21	14.85	61.98	36.63
1972	22.36	35.09	42.55	15.83	64.97	38.19
1971	19.32	34.24	46.44	18.61	65.76	37.93
1970	22.84	35.19	41.98	19.11	64.81	41.95
1969	22.91	36.94	40.14	18.83	63.06	41.74
1968	24.65	38.59	36.76	16.56	61.41	41.21
1967	23.67	37.52	38.82	16.00	62.48	39.67
1966	25.05	40.43	34.52	16.28	59.57	41.33
1965	23.81	36.83	39.36	18.95	63.17	42.76
1964	23.55	36.21	40.24	20.54	63.79	44.09
1963	23.31	36.83	39.86	18.31	63.17	41.62
1962	19.52	46.31	34.17	20.25	53.69	39.77
1961	19.75	49.36	30.89	18.20	50.64	37.94

NOTE: PRODUCT. - PRODUCTION

COST FACTORS AS A PERCENT OF SALES

SIC: 3761 GUIDED MISSILES, SPACE VEHICLES

YEAR	---------------- AS A PERCENT OF SALES ----------------					
	DIRECT LABOR	MATERIAL COSTS	OVERHEAD COSTS	INDIRECT LABOR	LOADED DIRECT	TOTAL LABOR
1983	9.40	34.28	56.32	19.82	65.72	29.22
1982	8.96	35.74	55.30	21.95	64.26	30.91
1981	8.96	32.16	58.88	25.77	67.84	34.73
1980	9.69	32.97	57.34	25.28	67.03	34.97
1979	11.08	32.02	56.90	25.24	67.98	36.32
1978	10.40	31.34	58.26	25.03	68.66	35.43
1977	11.37	31.82	56.81	24.99	68.18	36.36
1976	11.48	33.80	54.72	26.43	66.20	37.97
1975	11.81	35.53	52.66	24.84	64.47	36.65
1974	11.44	37.20	51.35	25.35	62.80	36.79
1973	12.28	31.80	55.92	26.88	68.20	39.17
1972	13.97	28.27	57.76	28.49	71.73	42.46
1971	14.16	27.07	58.77	30.10	72.93	44.26
1970	13.50	25.77	60.73	32.44	74.23	45.94
1969	13.04	24.87	62.09	32.77	75.13	45.81
1968	12.93	28.00	59.08	33.51	72.00	46.44
1967	12.65	28.06	59.29	32.59	71.94	45.24
1966	12.81	31.94	55.26	29.65	68.06	42.45
1965	12.76	31.34	55.90	31.79	68.66	44.56
1964	12.00	30.68	57.32	32.79	69.32	44.79
1963	13.36	37.36	49.28	29.82	62.64	43.18
1962						
1961						

NOTE: IF PART OR ALL OF A LINE IS BLANK, DATA IS NOT AVAILABLE

COST FACTORS AS A PERCENT OF SALES

SIC: 3764 SPACE PROPULSION UNITS, PARTS

YEAR	AS A PERCENT OF SALES					
	DIRECT LABOR	MATERIAL COSTS	OVERHEAD COSTS	INDIRECT LABOR COSTS	LOADED DIRECT WAGES	TOTAL LABOR
1983	11.87	34.46	53.67	21.07	65.54	32.95
1982	11.84	33.18	54.98	21.34	66.82	33.18
1981	12 19	33.01	54.80	23.52	66.99	35.71
1980	13.31	32.73	53.96	23.41	67.27	36.72
1979	13.22	32.24	54.54	25.35	67.76	38.58
1978	12.57	30.79	56.64	24.60	69.21	37.16
1977	11.84	33.40	54.76	25.90	66.60	37.74
1976	12.05	31.52	56.43	26.65	68.48	38.70
1975	11.75	35.81	52.44	25.39	64.19	37.14
1974	11.14	35.32	53.54	24.30	64.68	35.43
1973	10.43	33.83	55.74	22.87	66.17	33.30
1972	12.29	30.87	56.84	26.26	69.13	38.55
1971						
1970						
1969						
1968						
1967						
1966						
1965						
1964						
1963						
1962						
1961						

NOTE: IF PART OR ALL OF A LINE IS BLANK, DATA IS NOT AVAILABLE

COST FACTORS AS A PERCENT OF SALES

SIC: 3769 SPACE VEHICLE EQUIPMENT,NEC.

YEAR	AS A PERCENT OF SALES					
	DIRECT LABOR	MATERIAL COSTS	OVERHEAD COSTS	INDIRECT LABOR COSTS	LOADED DIRECT WAGES	TOTAL LABOR
1983	15.46	25.35	59.19	16.73	74.65	32.18
1982	15.58	32.94	51.48	14.30	67.06	29.88
1981	14.72	35.02	50.26	13.99	64.98	28.71
1980	15.05	33.90	51.05	23.24	66.10	38.29
1979	17.44	32.23	50.33	23.84	67.77	41.28
1978	17.25	38.54	44.20	26.68	61.46	43.94
1977	16.22	32.45	51.33	24.78	67.55	41.00
1976	12.02	27.61	60.37	27.08	72.39	39.10
1975	14.18	27.59	58.23	27.29	72.41	41.46
1974	14.96	32.27	52.77	25.88	67.73	40.84
1973	11.10	35.38	53.52	25.33	64.62	36.42
1972	10.53	36.29	53.17	26.14	63.71	36.68
1971						
1970						
1969						
1968						
1967						
1966						
1965						
1964						
1963						
1962						
1961						

IF PART OR ALL OF A LINE IS BLANK, DATA IS NOT AVAILABLE

END
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DTIC